

**LONG-TERM TRENDS IN THE  
RELATIVE ABUNDANCE OF CRAYFISH  
FROM ACID SENSITIVE, SOFTWATER  
LAKES IN SOUTH CENTRAL ONTARIO:  
A DATA SUMMARY FOR THE FIRST  
5 YEARS, 1988-1992**

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A DATA SUMMARY FOR THE FIRST 5 YEARS, 1988 - 1992**

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## EXECUTIVE SUMMARY

In 1988, the Biological Studies Unit of the Limnology Section initiated a monitoring programme to assess long-term trends in benthic invertebrate communities in acid sensitive, softwater Precambrian Shield lakes. One goal of this programme was to examine temporal trends in crayfish relative abundance with reference to lake chemistry, especially lake pH. This report summarizes the biological and chemical data collected from 14 lakes from 1988 to 1992. The mid-lake surface pH of these lakes ranged from 5.07 to 6.88.

Crayfish were trapped using baited minnow traps. Three crayfish species were captured (Cambarus bartoni, Orconectes propinquus, and Orconectes virilis), with a range of 0-3 species per lake. C. bartoni occurred in nine lakes, whereas O. propinquus and O. virilis each occurred in six lakes. Male crayfish were caught in greater numbers than females for C. bartoni and O. virilis (41% ♀ : 59% ♂ and 40% ♀ : 60% ♂ respectively), but not for O. propinquus (51% ♀ : 49% ♂). For all species, Form I males were usually the largest crayfish caught, whereas the Form II males and females were slightly smaller on average. O. propinquus was the smallest crayfish species.

The catch per unit effort (CPUE; i.e., the number of crayfish caught per trap per night) ranged from 0.02 to 17.7 for C. bartoni, 0.06 to 9.10 for O. propinquus, and 0.01 to 2.54 for O. virilis over the five-year period. The percentage of the catch that was C. bartoni from lakes with more than 1 species ranged from 2.1% to 81.4%. In comparison, O. propinquus percentages ranged from 18.6% to 96.3%, and O. virilis percentages ranged from 1.2% to 97.9%. There was an apparent decline in total CPUE in 8 of the 14 lakes over the 5-year period. The catch of C. bartoni declined in 7 of 9 lakes where it was encountered. By contrast, CPUE of O. propinquus and O. virilis decreased in 3 and 2 of 6 lakes, respectively. The cause of these declines in crayfish CPUE was not determined.

There were considerable differences in alkalinity, aluminum and pH values among the lakes. Two of the four lakes with the highest pH values also had some of the highest crayfish

catches. There was little within-lake variation in alkalinity and pH over the 5 year period; however, increasing concentrations of aluminum were recorded from 10 of the 14 lakes during this same period. The concomitant increase in aluminum and decline in crayfish CPUE warrants continued study.

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## INTRODUCTION

In 1988, the Ontario Ministry of the Environment (MOE) initiated a biomonitoring programme to assess long-term trends in the composition of benthic invertebrate communities in acid-sensitive, softwater Precambrian Shield lakes (Reid et al. 1993). This work represents one MOE component of the federal-provincial Long Range Transport of Airborne Pollutants (LRTAP) programme that will assess anticipated regional changes in the health of inland aquatic ecosystems associated with reductions in sulphur emissions (Shaw et al. 1992). The goals of the LRTAP biomonitoring programme are: (1) to estimate common species distributions, (2) to compare relative abundances of invertebrate taxa among lakes and among regions, and (3) to detect shifts in invertebrate relative abundance in response to anticipated changes in water chemistry associated with emission controls. This type of intensive long-term monitoring programme is essential to fully assess the degree of natural variation relative to expected responses to anthropogenic stress (Schindler 1987).

Many benthic invertebrates including snails, clams, crayfish, amphipods and several aquatic insects perish in low pH conditions (Dillon et al. 1984, Okland and Okland 1986, Mackie 1989). For example, experimental additions of acid to a lake in northwestern Ontario resulted in the eradication of the crayfish, Orconectes virilis (France 1987, 1993, Davies 1989). Moreover, Berrill et al. (1985) found that O. propinquus and O. rusticus perished in low pH water (i.e., pH 4.5-5.0) that did not affect Cambarus robustus. Because orconectids are sensitive to low pH (Berrill et al. 1985, France 1987, Malley 1980), and they are found in south central Ontario (Crocker and Barr 1968), a subcomponent of the biomonitoring programme was designed to monitor crayfish relative abundance over time.

This report summarizes crayfish catches in baited traps from 12 - 14 study lakes over a 5 year period, from 1988 to 1992. These results are summarized with information on: (1) the occurrence, catch per unit effort and the proportion of males and females in the total catches, (2) the size distribution of the catch, and (3) water chemistry data for each lake.

## METHODS

### Lake and Site Selection

In 1988, twelve lakes were selected from the MOE lake chemistry database to span a range of alkalinities from  $<0 \mu\text{eq} \cdot \text{L}^{-1}$  to  $100 \mu\text{eq} \cdot \text{L}^{-1}$  (App. 3). Two lakes were added in 1990 to increase the representation of lakes in the low-alkalinity range: Heney ( $10 \mu\text{eq} \cdot \text{L}^{-1}$ ) and Pearceley ( $-3 \mu\text{eq} \cdot \text{L}^{-1}$ ) lakes. All 14 lakes are within the area bounded by North Bay, Gravenhurst and Algonquin Provincial Park (Figure 1). Eight lakes lie on the Algonquin-Haliburton Highlands ( $>340$  m above sea level): Clear, Cradle, Delano, Heney, Pearceley, Pincher, Plastic, Westward. The remaining six lakes are in the Lake Algonquin basin, formed after the Wisconsin glaciation (Blue Chalk, Crosson, Hamer, Harp, Skidway and Young; Appendix 1). All of the lakes are located on the Precambrian Shield in south central Ontario where sulphate deposition is high ( $0.75 - 1.25 \text{ g} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$ ; Neary and Dillon 1988). Locations and physical descriptions of the lakes are provided in Table 1. Detailed descriptions of the study lakes, including watershed geology and vegetation are presented in Reid et al. (1993).

An initial nearshore survey of the lakes was conducted in the summer of 1988 to identify potential sampling sites that were representative of the predominant littoral habitat types of each lake. The field crew circumnavigated each lake, and identified sections of the littoral zone that represented each of the dominant substrate types. Nearshore substrates included bedrock (BDR), boulders (BOU), cobble (COB), pebble (PEB), silt (SLT), sand (CSD) and detritus (i.e., substrates with a large proportion of organic material including woody debris - LOS). Several sites also had a high percentage of macrophyte cover. These macrophyte areas are important to crayfish because macrophytes provide refuge from predators (Lodge et al. 1986).

After circumnavigating the lake, three sites were selected as typical sites for subsequent trapping. The three sites were characterized as: (1) rocky; (2) silt or sand; and (3) detritus with woody debris. After selecting the sites in 1988, SCUBA divers provided substrate

descriptions from the shore to approximately 6 metres in depth, the maximum depth of the crayfish traps. Each site was divided into 3 sections: 0 - 2 m, 2 - 4 m, and 4 - 6 m, and the dominant substrates occurring in each section were recorded, as well as macrophyte cover, wherever present. Substrate descriptions for each of the sites in the 14 lakes are listed in Table 2. Descriptions for Pincher Lake are only available for the 0 - 2 m depth since this lake was not surveyed by divers. Similarly, substrate descriptions for Heney and Pearceley lakes are only available for the 0 - 2 m depth since these lakes were not sampled prior to 1990.

### **Water Chemistry Sampling Procedures**

Water samples were collected by the MOE field sampling crew using methods described by Girard and Reid (1990). In most lakes samples were collected at monthly intervals as volume-weighted composites from the deepest spot of the lake. All samples were refrigerated and returned to the water chemistry lab for analysis within 24 hours. The chemical parameters included alkalinity, aluminum, calcium, chloride, conductivity, dissolved organic carbon, dissolved inorganic carbon, iron, potassium, magnesium, sodium, nitrogen, pH, sulphate and total phosphorus (Appendix 2). The data are summarized as ice-free means with the exception of Hamer and Young lakes in 1988 because water samples were only collected once in the fall of 1988 in these 2 lakes (Appendix 3).

### **Fisheries Data**

The Ontario Ministry of Natural Resources (MNR) in Bracebridge, Minden and Parry Sound provided data on the occurrences of fish species in the study lakes. Fish species were sampled with various types of gear including experimental gill nets, trapnets, Windermere traps, minnow traps and seine nets. Fisheries information is important in the assessment of crayfish catch data because several fish species prey on crayfish and hence, the occurrence of these fish species is believed to affect crayfish abundance estimates based on trap catches (Steele 1977, Collins et al. 1983).

## Crayfish Sampling Procedures

Crayfish were collected with modified wire mesh minnow traps. Funnel entrances were enlarged to 3.5 cm (Collins et al. 1983) to accommodate large crayfish. In 1988 ten traplines were set perpendicular to the shore at each of the three sites. Each trapline consisted of 6 traps set at 1-m depth intervals from 1 m to 6 m. Traps were marked with 2-litre plastic bottles attached to a measured length of rope. Initially 180 traps were set in each lake with the exception of Clear, Crosson, Hamer and Skidway where fewer traps were used because of the shallow depths at one site (i.e., 4 metres). However, the number of traps varied from 1989 to 1992 (Table 3), although the traps were set in a similar manner. Each lake was sampled for one night during July or August from 1988 to 1992.

Traps were baited with fish-flavoured canned cat food that was placed in a single perforated plastic film canister in each trap. Traps were set in the afternoon and retrieved the following day. To reduce bias possibly arising from escapement during the trapping period, traps were set and picked up from the sites in random order. Crayfish were trapped during the intermoult season of July and August. This midsummer sampling period is the best time to estimate crayfish relative abundance because trap catches exhibit minimal seasonal variation at this time (Capelli and Magnuson 1983, Somers and Green 1993).

Data for each crayfish collection were recorded with information on lake, date, site and trap number. Species, sex and carapace length were recorded for each crayfish. Crayfish were identified using the keys in Crocker and Barr (1968). The sex of each crayfish was classified as male Form I (sexually functional male) or Form II (sexually non-functional male), or female. Dorsal carapace length was measured with vernier calipers in mm to one decimal place. Carapace length was defined as the distance between the tip of the acumen (the extreme anterior end of the rostrum) and the posterior end of the cephalothorax. Appendix 8 summarizes the standard operating procedures that were followed each year.

## Lake Descriptions

The study lakes are located in four districts: Muskoka, Haliburton, Parry Sound and Nipissing. The latitude ranges from  $45^{\circ} 05'$  to  $45^{\circ} 42'$  and the longitude ranges from  $78^{\circ} 35'$  to  $79^{\circ} 48'$  (Figure 1). All of the lakes are small headwater lakes (17.9 ha to 105.9 ha) from five tertiary watersheds in south central Ontario (i.e., 2EA - Georgian Bay Tributaries, 2EB - Moon River and Go Home River, 2EC - Severn River, 2HF - Cameron Lake Drainage and 2KD - Upper Madawaska River; Table 1). Watersheds 2EA, 2EB and 2EC all flow into Georgian Bay of Lake Huron. Watershed 2HF flows into Lake Ontario and watershed 2KD flows into the St. Lawrence drainage area (Cox 1978).

## DATA SUMMARY

Substrate descriptions for each trapping site are listed in Table 2. One site in Blue Chalk, Clear, Delano, Harp and Young lakes, and 2 sites on Westward Lake all had similar substrate characteristics. These sites were comprised of predominately macrophytes, mud and sand (i.e., MAC, MUD and CSD or MSD or FSD) and are classified as Type 1 in Table 2. One site on Clear, Crosson, Pearceley, Westward and Young lakes was composed of cobbles, or cobbles and boulders. Two sites on Blue Chalk and Cradle lakes consisted mostly of cobbles and boulders. This type of rocky site is indicated as type 2 in Table 2.

One site on Clear Lake and all sites on Hamer Lake consisted mostly of mud (type 3). Single sites on each of Heney Lake and Pincher Lake were similar (CPO, LOG, LOS); however, this predominately detritus description only represents the first 2 metres, because SCUBA divers did not survey these two lakes. The remainder of the sites (26) had unique substrate combinations.

## Water Chemistry

Water chemistry results are tabulated in Appendix 3 to document changes over the five-year sampling period. pH ranged from 5.07 (Hamer Lake) to 6.88 (Young Lake), whereas alkalinity (total inflection point) ranged from  $-0.09 \text{ mg} \cdot \text{L}^{-1}$  (Pearceley Lake) to  $6.59 \text{ mg} \cdot \text{L}^{-1}$  (Young Lake). There was considerable variation in alkalinity, aluminium and pH values among the lakes; however, there was little within-lake variation over the 5-year period (Appendix 3). One exception is a noticeable increase in the concentration of aluminium in many of the lakes (i.e., all lakes with the exception of Hamer, Westward and Young lakes; Figures 2-5).

There was modest within-lake variation and substantial between-lake variation in calcium, conductivity and magnesium (Appendix 3). Conductivity appears to increase over time in Harp Lake, probably because of the application of road salt in the Harp Lake watershed. An increase in DIC is evident for Pincher Lake and a decline in DOC for Hamer Lake.  $\text{SO}_4$  declined in Clear Lake, but increased in Delano Lake. There is considerable between-lake variation in  $\text{NO}_3$ , TKN and TP, with a decline in TKN in Hamer Lake and an increase in TP in Skidway Lake.

## Fisheries Data

The MNR fish surveys revealed that 27 fish species representing 10 taxonomic families were found in the 14 lakes (Table 4; Gunn et. al. 1988). Lake trout were found in 5 lakes (i.e., Blue Chalk, Clear, Cradle, Delano and Harp) and brook trout were present in 4 lakes (i.e., Crosson, Harp, Pearceley, Westward). In addition, smallmouth bass were captured in 4 lakes (i.e., Harp, Hamer, Heney and Young). Skidway Lake has a largemouth bass population. All of these bass lakes are in the Moon River and Go Home River watershed (i.e., 2EB) and crayfish catches were much lower in these lakes than in other lakes in the same watershed, that do not support bass populations (e.g., Westward and Pincher). Since

bass are important crayfish predators (Collins et al. 1983), their presence in these lakes may contribute to the low CPUE.

Brown bullheads were present in all of the watersheds (Pearceley, Hamer, Heney, Blue Chalk, Crosson and Plastic lakes), with the exception of the lakes in the 2KD watershed (Upper Madawaska River). This species also preys on crayfish (Scott and Crossman, 1975) and its frequency in our trap catches increased in Pearceley Lake. Concomitantly, our CPUE of crayfish in Pearceley Lake declined from 0.40 to 0 over a three-year period (Figure 8). In contrast, the CPUE for Hamer and Heney lakes was comparatively stable over the same period (these 2 lakes have smallmouth bass populations). Many factors affect crayfish catch and the presence of predatory fish is only one of these; however, the presence or absence of several predatory species appears to correspond with differences in crayfish CPUE (Collins et al. 1983, Somers and Green 1993).

#### **Crayfish Catch Data - Presence/Absence**

Three species of crayfish were present in the 14 study lakes: C. bartoni, O. propinquus and O. virilis (Table 5). Two lakes had all three species (Blue Chalk for all years and Delano in 1988 and 1989), four lakes had two species (Clear, Crosson, Harp in 1988 and 1989, and Westward), and the remaining seven lakes each had only one species. Crayfish were found in all lakes with the exception of Plastic Lake. No crayfish have been found in Plastic Lake since 1981 (i.e., O. virilis; N.C. Collins, pers. comm.). C. bartoni was found in Pearceley Lake in 1990 and 1991, but not in 1992.

Differences in the species distributions among lakes can be attributed to many factors, including dispersal (Capelli and Magnuson 1983). The three species found in the study lakes are native to Ontario, having followed the retreating glaciers (Crocker and Barr 1968). Differences in species composition probably reflect different migration routes, since the 14 study lakes encompass 5 different watersheds.

The proportions of the different crayfish species in the catch are shown in Table 6 for those lakes where more than one species was captured. The proportion of C. bartoni ranged from 2.1% (Crosson) to 81.4% (Westward). In Blue Chalk, Clear and Crosson lakes, C. bartoni comprised the smallest percentage of the catch over the five-year period, whereas C. bartoni represented the largest percentage of the catch in Harp and Westward lakes. In Delano Lake, C. bartoni were less abundant than O. propinquus but more abundant than O. virilis.

All three species were found in 3 of the 5 watersheds (2EB, 2EC and 2KD). C. bartoni was the only species found in the 2EA watershed, but only one lake was sampled. Similarly, O. virilis was not caught in watershed 2HF, but only 2 lakes were sampled in this watershed. More lakes should be sampled in these watersheds before making conclusions regarding crayfish distribution patterns.

O. propinquus comprised the greatest percentage of the catch in Blue Chalk, Clear and Delano lakes, but the lowest percentage in Harp and Westward. In Blue Chalk Lake O. virilis was caught in greater numbers than C. bartoni, but O. virilis was less abundant than O. propinquus. In 1990, the catch of O. virilis almost equalled the catch of O. propinquus in Blue Chalk Lake. By contrast, O. virilis comprised the greatest part of the catch in Crosson Lake and the least in Delano (Table 6).

#### **Crayfish CPUE (Catch per unit Effort)**

Figures 6 through 9 summarize the catch per unit effort (CPUE) of all species over the five-year period. The CPUE ranged from 0.02 to 17.7 for C. bartoni, 0.06 to 9.10 for O. propinquus, and 0.01 to 2.54 for O. virilis. There was a general decline in the average number of crayfish caught over the five-year period. This trend is evident in many lakes with the exception of Blue Chalk, Delano, Hamer, Heney and Westward.

C. bartoni exhibited a decline in CPUE in 7 of 9 lakes where it was captured (Figures 6-9). By contrast, the CPUE of O. propinquus decreased in 3 of 6 lakes, whereas O. virilis catches

declined in only 2 of 6 lakes. In Delano Lake, C. bartoni was only caught in 1988, 1989 and 1991, and O. virilis was not captured after 1989. In Harp Lake, O. propinquus was not captured after 1990 and C. bartoni was not caught after 1989 (Table 7). Similarly, C. bartoni was not caught in Pearceley Lake in 1992 and no crayfish were captured in Plastic Lake over the 5 years.

### Male:Female Catch Ratios

It is widely recognized that traps tend to select for males of the most aggressive species (Abrahamsson and Goldman 1970, Collins et al. 1983). Over the five-year period predominantly more male crayfish were caught for C. bartoni (41% ♀ : 59% ♂) and O. virilis (40% ♀ : 60% ♂), but not for O. propinquus (51% ♀ : 49% ♂; Table 8, Appendix 4). Fewer females were caught each year for C. bartoni, whereas fewer female O. propinquus were caught from 1989 to 1991 (49%). Female O. virilis were caught less frequently for all years except 1992 when the ratio was 50:50. The observed differences in the male:female ratios may reflect year-to-year variation in moulting patterns that appear to vary with respect to water temperature (e.g., Somers and Green 1993). These differences may have been emphasized because the lakes were not sampled in the same order each year.

### Carapace Lengths

Mean carapace lengths for each species, by lake and year are provided in appendices 5, 6 and 7. Overall means for 1988 to 1992 are illustrated in Figure 10. O. propinquus had the smallest carapace lengths as expected, since this is the smallest species of crayfish in Ontario (Crocker and Barr, 1968). The largest crayfish were O. virilis from Hamer Lake. Form I males were usually the largest crayfish caught, whereas the Form II males and females were slightly smaller on average.

Of the seven lakes where C. bartoni was found, the smallest animals (i.e., mean size) were captured in Cradle Lake which had the highest CPUE. Perhaps competition for limited food resources affects growth rates and hence, mean carapace length (e.g., see Abrahamsson and Goldman 1970, France 1985, Hazlett and Rittschof 1985). This may also be true for the small average size of O. propinquus in Blue Chalk Lake.

## RECOMMENDATIONS

Many factors affect the presence or absence of crayfish. These factors include water chemistry (Schindler 1985, France 1993), habitat (Jones and Momot 1991), presence and/or abundance of predatory fish (Collins et al. 1983), presence of other crayfish species (Somers and Green 1993) and dispersal (Capelli and Magnuson 1983). All of these factors must be considered when comparing crayfish catches. For example, in 1992 no crayfish were caught in Pearceley Lake, but brown bullheads were captured in large numbers. These fish are known to prey on crayfish and perhaps some crayfish were eaten while in the traps. As a result, the stomach contents of large predatory fish caught in the traps should be examined for fresh crayfish remains. In addition, a second night of trapping effort may be warranted if the trap catches are inconsistent with data from previous years.

Because biogeographic distribution may also be important, crayfish distributions patterns should be determined by trapping lakes in different watersheds of the Muskoka-Haliburton area (e.g., David and Reid 1993). It is important to determine if a species is absent because of biotic or anthropogenic factors, or if the species is absent because it never colonized the watershed after the last glacial retreat.

This biomonitoring programme must differentiate between natural variation and anticipated responses to anthropogenic stresses. As a result, these sorts of programmes should utilize simple, yet cost-effective protocols that can be used year after year. Our standard operating procedures are summarized in Appendix 8 to ensure consistency in sampling and data processing across years. However, within-year variation in CPUE should be quantified by

repeatedly trapping several lakes with different crayfish species compositions and different densities.

The apparent decline in crayfish CPUE and concomitant increase in aluminum concentration in many of the study lakes warrants further study, especially given the results of laboratory studies linking pH, aluminum and the inhibition of calcium uptake with increased mortality in O. virilis (Malley and Chang 1985).

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**Table 1** Location and physical description of the study lakes.

| Lake Name and Abbreviation | Watershed | Latitude (°N) | Longitude (°W) | Topographic Map | District    | Township  | Area (ha) | Elevation (mASL) | Mean Depth (m) | Max Depth (m) |
|----------------------------|-----------|---------------|----------------|-----------------|-------------|-----------|-----------|------------------|----------------|---------------|
| Blue Chalk (BC)            | 2EC15     | 45°12'        | 78°56'         | 31E2            | Muskoka     | Ridout    | 52.4      | 336.0            | 8.5            | 23.0          |
| Clear (CL)                 | 2HF08     | 45°11'        | 78°43'         | 31E2            | Haliburton  | Sherborne | 88.4      | 369.0            | 12.4           | 33.0          |
| Cradle (CR)                | 2KD18     | 45°28'        | 78°35'         | 31E7            | Haliburton  | Lawrence  | 17.9      | 472.4            | 12.4           | 33.3          |
| Crosson (CN)               | 2EC15     | 45°05'        | 79°02'         | 31E3            | Muskoka     | Oakley    | 56.7      | 312.0            | 9.2            | 25.0          |
| Delano (DO)                | 2KD01     | 45°31'        | 78°36'         | 31E10           | Nipissing   | Canisbay  | 23.9      | 442.0            | 7.1            | 18.6          |
| Hamer (HR)                 | 2EB05     | 45°14'        | 79°48'         | 31E4            | Parry Sound | Humphrey  | 35.2      | 221.0            | 3.3            | 8.5           |
| Harp (HP)                  | 2EB13     | 45°23'        | 79°07'         | 31E6            | Muskoka     | Chaffey   | 71.4      | 328.6            | 13.3           | 37.5          |
| Henev (HY)                 | 2EB09     | 45°08'        | 79°06'         | 31E3            | Muskoka     | McLean    | 21.4      | 345.5            | 3.3            | 5.8           |
| Pearceley (PY)             | 2EA19     | 45°42'        | 79°30'         | 31E11/12        | Parry Sound | Chapman   | 44.1      | 358.4            | 4.7            | 8.1           |
| Pincher (PR)               | 2EB13     | 45°34'        | 78°51'         | 31E10           | Nipissing   | McCrancy  | 42.1      | 510.5            | 6.1            | 15.5          |
| Plastic (PC)               | 2HF10     | 45°11'        | 78°50'         | 31E2            | Haliburton  | Sherborne | 32.1      | 376.4            | 7.9            | 16.3          |
| Skidway (SY)               | 2EB02     | 45°12'        | 79°52'         | 31E4            | Parry Sound | Conger    | 18.5      | 221.0            | 2.9            | 7.8           |
| Westward (WD)              | 2EB11     | 45°29'        | 78°47'         | 31E7            | Nipissing   | Peck      | 63.3      | 429.0            | 20.5           | 44.0          |
| Young (YG)                 | 2EB07     | 45°13'        | 79°33'         | 31E4            | Muskoka     | Watt      | 105.9     | 252.0            | 12.0           | 21.1          |

Table 2 Substrate types at each of the 3 trapping sites in the study lakes.

| Lake       | Site #1<br>Metres<br>2-4 |                   | Site #2<br>Metres<br>2-4 |                   | Site #3<br>Metres<br>2-4 |                          |
|------------|--------------------------|-------------------|--------------------------|-------------------|--------------------------|--------------------------|
|            | 0-2                      | 4-6               | 0-2                      | 4-6               | 0-2                      | 4-6                      |
| Blue Chalk | (Type 1)                 |                   | (Type 2)                 |                   | (Type 2)                 |                          |
|            | MAC<br>LOG               | MSD<br>MUD        | CPO<br>COB               | COB<br>BOU        | SLT<br>CPO<br>COB        | BOU<br>LOG<br>CPO<br>COB |
| Clear      | (Type 1)                 |                   | (Type 2)                 |                   | (Type 3)                 |                          |
|            | MAC<br>MSD<br>MUD        | MSD<br>MUD        | COB                      | COB               | COB<br>MUD               | MUD                      |
| Cradle     | (Type 2)                 |                   | (Type 2)                 |                   | (Type 2)                 |                          |
|            | MSD<br>MUD<br>BDR        | COB               | MSD<br>COB               | MSD<br>MAC<br>COB | BDR<br>COB               | BOU                      |
| Crosson    | (Type 2)                 |                   | (Type 2)                 |                   | (Type 2)                 |                          |
|            | PEB<br>BDR               | MUD<br>BOU<br>PEB | CPO<br>COB               | COB               | CPO<br>PEB               | SLT<br>LOS               |
| Delano     | (Type 1)                 |                   | (Type 1)                 |                   | (Type 1)                 |                          |
|            | MAC                      | MSD<br>MUD        | LOG<br>BDR               | BDR<br>MSD<br>COB | LOG<br>COB               | BOU<br>COB<br>MSD        |

Table 2 (continued)...

|                        | Site #1<br>Metres<br>2-4        | 4-6        | 0-2               | Site #2<br>Metres<br>2-4 | 4-6 | 0-2                      | Site #3<br>Metres<br>2-4 | 4-6        |
|------------------------|---------------------------------|------------|-------------------|--------------------------|-----|--------------------------|--------------------------|------------|
| Lake                   | 0-2                             | 4-6        | 0-2               | 2-4                      | 4-6 | 0-2                      | 2-4                      | 4-6        |
| Hamer                  | COB<br>LOG<br>FPO<br>LOS<br>MUD | MUD        | CPO<br>FPO<br>MUD | (Type 3)<br>MUD          | MUD | BDR<br>PEB<br>MUD        | (Type 3)<br>MUD          | MUD        |
| Harp                   | MAC<br>CPO<br>CSD<br>MUD        | MUD<br>SLT | COB<br>BOU        | (Type 3)<br>CSD<br>MUD   | --  | LOG<br>CPO<br>COB<br>BOU | (Type 2)<br>COB<br>BOU   | COB<br>BOU |
| Heney<br>(no dive)     | CPO<br>LOS<br>LOG               |            | COB<br>LOG<br>CPO |                          |     | LOS<br>MAC-E<br>MAC-S    |                          |            |
| Pearceley<br>(no dive) | MAC-S<br>MSD<br>CPO             |            | BDR<br>COB<br>MSD | (Type 2)                 |     | CPO<br>LOS<br>MSD        |                          |            |
| Pincher<br>(no dive)   | MAC-E<br>SLT<br>LOG<br>LOS      |            | CPO<br>LOG<br>LOS |                          |     | SLT<br>LOG<br>BOU        |                          |            |

Table 2 (continued)...

|          | Site #1<br>Metres | Site #2<br>Metres | Site #3<br>Metres |
|----------|-------------------|-------------------|-------------------|
| Lake     | 0-2               | 0-2               | 0-2               |
|          | 4-6               | 4-6               | 4-6               |
| Skidway  | (Type 1)          | (Type 1)          | (Type 1)          |
| CPO      | MUD               | MUD               | MUD               |
| LOG      | FSD               | FSD               | FSD               |
| FPO      | MAC               | MAC-S             | MAC-S             |
| MAC      |                   | LOG               | MAC               |
|          |                   | LOS               |                   |
| Westward | (Type 1)          | (Type 2)          | (Type 1)          |
| MAC      | COB               | BOU               | MSD               |
| COB/MSD  | MSD               | LOG               | COB               |
|          | MUD               | BOU               | MSD               |
| Young    | (Type 2)          | (Type 1)          |                   |
| COB      | MSD               | COB               | BDR               |
| COB/MSD  | COB/MSD           | BOU               | COB               |
|          |                   | MSD               |                   |
|          |                   | MAC-S             | CPO               |
|          |                   | COB               | FPO               |
|          |                   | MSD               | LOG               |
|          |                   |                   | BDR               |
|          |                   |                   | COB               |

Detailed descriptions (0-2, 2-4, 4-6 m) compiled by divers.

Key to substrate codes shown in Appendix 8, Table 1.

Type 1, 2 and 3 - see text.

Table 3 Total crayfish catch and sampling effort for the period 1988 - 1992.

| Lake Name  | Sampling Date  | Species Code | Number of Females | Number of Males | Total Catch | No. of Traps | CPUE | Total CPUE |
|------------|----------------|--------------|-------------------|-----------------|-------------|--------------|------|------------|
| Blue Chalk | July 22, 1988  | Cb           | 63                | 111             | 174         | 178          | 0.98 | 6.28       |
|            |                | Op           | 359               | 387             | 746         |              | 4.19 |            |
|            |                | Ov           | 85                | 113             | 198         |              | 1.11 |            |
|            | July 13, 1989  | Cb           | 26                | 19              | 45          | 60           | 0.75 | 11.58      |
|            |                | Op           | 264               | 282             | 546         |              | 9.10 |            |
|            |                | Ov           | 39                | 65              | 104         |              | 1.73 |            |
|            | July 24, 1990  | Cb           | 3                 | 3               | 6           | 18           | 0.33 | 4.16       |
|            |                | Op           | 14                | 22              | 36          |              | 2.00 |            |
|            |                | Ov           | 5                 | 28              | 33          |              | 1.83 |            |
|            | July 5, 1991   | Cb           | 20                | 14              | 34          | 54           | 0.63 | 5.44       |
|            |                | Op           | 88                | 114             | 202         |              | 3.74 |            |
|            |                | Ov           | 28                | 30              | 58          |              | 1.07 |            |
|            | June 30, 1992  | Cb           | 13                | 12              | 25          | 54           | 0.46 | 6.11       |
|            |                | Op           | 130               | 105             | 235         |              | 4.35 |            |
|            |                | Ov           | 37                | 33              | 70          |              | 1.30 |            |
| Clear      | July 25, 1988  | Cb           | 50                | 99              | 149         | 154          | 0.97 | 3.05       |
|            |                | Op           | 165               | 155             | 320         |              | 2.08 |            |
|            | August 2, 1989 | Cb           | 32                | 58              | 90          | 60           | 1.50 | 2.90       |
|            |                | Op           | 38                | 46              | 84          |              | 1.40 |            |
|            | July 19, 1990  | Cb           | 5                 | 37              | 42          | 18           | 2.33 | 4.22       |
|            |                | Op           | 14                | 20              | 34          |              | 1.89 |            |
|            | July 9, 1991   | Cb           | 3                 | 27              | 30          | 54           | 0.56 | 3.28       |
|            |                | Op           | 77                | 70              | 147         |              | 2.72 |            |
|            | July 16, 1992  | Cb           | 2                 | 26              | 28          | 53           | 0.53 | 1.44       |
|            |                | Op           | 21                | 27              | 48          |              | 0.91 |            |

Table 3 (continued) ...

| Lake Name | Sampling Date   | Species Code | Number of Females | Number of Males | Total Catch | No. of Traps | CPUE  | Total CPUE |
|-----------|-----------------|--------------|-------------------|-----------------|-------------|--------------|-------|------------|
| Cradle    | August 30, 1988 | Cb           | 1077              | 1137            | 2214        | 180          | 12.30 | 12.30      |
|           | August 1, 1989  |              | 508               | 548             | 1056        | 60           | 17.60 | 17.60      |
|           | July 5, 1990    |              | 71                | 112             | 183         | 18           | 10.17 | 10.17      |
|           | July 19, 1991   |              | 118               | 180             | 298         | 18           | 16.56 | 16.56      |
|           | July 7, 1992    |              | 131               | 248             | 379         | 53           | 7.15  | 7.15       |
| Grosson   | July 20, 1988   | Cb           | 47                | 38              | 85          | 155          | 0.55  | 3.07       |
|           |                 | Ov           | 165               | 225             | 390         |              |       | 2.52       |
|           | August 1, 1989  | Cb           | 4                 | 10              | 14          | 60           | 0.23  | 1.51       |
|           |                 | Ov           | 26                | 51              | 77          |              | 1.28  |            |
|           | August 9, 1990  | Cb           | 1                 | 3               | 4           | 54           | 0.07  | 0.63       |
|           |                 | Ov           | 9                 | 21              | 30          |              | 0.56  |            |
|           | July 30, 1991   | Cb           | 9                 | 4               | 13          | 54           | 0.24  | 0.80       |
|           |                 | Ov           | 11                | 19              | 30          |              | 0.56  |            |
|           | July 9, 1992    | Cb           | 0                 | 1               | 1           | 54           | 0.02  | 0.87       |
|           |                 | Ov           | 23                | 23              | 46          |              | 0.85  |            |
| Delano    | August 11, 1988 | Cb           | 3                 | 1               | 4           | 180          | 0.02  | 0.91       |
|           |                 | Op           | 105               | 53              | 158         |              | 0.88  |            |
|           |                 | Ov           | 2                 | 0               | 2           |              | 0.01  |            |
|           | July 18, 1989   | Cb           | 3                 | 2               | 5           | 60           | 0.08  | 1.15       |
|           |                 | Op           | 36                | 27              | 63          |              | 1.05  |            |
|           |                 | Ov           | 0                 | 1               | 1           |              | 0.02  |            |
|           | July 4, 1990    | Op           | 14                | 1               | 15          | 36           | 0.42  | 0.42       |
|           | July 19, 1991   | Cb           |                   | 3               | 3           | 54           | 0.06  | 0.78       |
|           |                 | Op           | 16                | 23              | 39          |              | 0.72  |            |
|           | July 7, 1992    | Op           | 28                | 21              | 49          | 54           | 0.91  | 0.91       |

Table 3 (continued) ...

| Lake Name | Sampling Date   | Species Code | Number of Females | Number of Males | Total Catch | No. of Traps | CPUE | Total CPUE |
|-----------|-----------------|--------------|-------------------|-----------------|-------------|--------------|------|------------|
| Hamer     | August 4, 1988  | Ov           | 37                | 17              | 54          | 160          | 0.34 | 0.34       |
|           | July 26, 1989   |              | 22                | 52              | 74          | 60           | 1.23 | 1.23       |
|           | July 11, 1990   |              | 2                 | 18              | 20          | 33           | 0.61 | 0.61       |
|           | August 1, 1991  |              | 10                | 34              | 44          | 54           | 0.81 | 0.81       |
| Harp      | July 3, 1992    |              | 16                | 19              | 35          | 54           | 0.65 | 0.65       |
|           | July 28, 1988   | Cb           | 8                 | 13              | 21          | 180          | 0.12 | 0.17       |
|           | July 14, 1989   | Op           | 7                 | 2               | 9           | 180          | 0.05 | 0.14       |
|           | July 12, 1990   | Op           | 1                 | 3               | 4           | 60           | 0.07 | 0.06       |
| Heney     | July 11, 1991   | Op           | 2                 | 2               | 4           | 60           | 0.07 | 0.06       |
|           | July 8, 1992    | Op           | 1                 | 1               | 2           | 36           | 0.06 | 0.00       |
|           | July 27, 1990   | Ov           | 15                | 10              | 25          | 54           | 0.46 | 0.46       |
|           | July 9, 1991    |              | 6                 | 9               | 15          | 54           | 0.28 | 0.28       |
| Pearceley | July 8, 1992    |              | 13                | 12              | 25          | 54           | 0.46 | 0.46       |
|           | July 6, 1990    | Cb           | 4                 | 20              | 24          | 60           | 0.40 | 0.40       |
|           | July 23, 1991   |              | 5                 | 4               | 9           | 54           | 0.17 | 0.17       |
|           | July 14, 1992   |              |                   |                 | 0           | 54           | 0.00 | 0.00       |
| Pincher   | August 28, 1988 | Cb           | 313               | 180             | 493         | 180          | 2.74 | 2.74       |
|           | July 21, 1989   |              | 43                | 62              | 105         | 60           | 1.75 | 1.75       |
|           | July 10, 1990   |              | 1                 | 6               | 7           | 18           | 0.39 | 0.39       |
|           | July 23, 1991   |              | 15                | 7               | 22          | 54           | 0.41 | 0.41       |
|           | July 14, 1992   |              | 6                 | 3               | 9           | 54           | 0.17 | 0.17       |

Table 3 (continued) ...

| Lake Name | Sampling Date   | Species Code | Number of Females | Number of Males | Total Catch | No. of Traps | CPUE | Total CPUE |
|-----------|-----------------|--------------|-------------------|-----------------|-------------|--------------|------|------------|
| Plastic   | July 18, 1988   |              |                   |                 | 0           | 180          | 0.00 | 0.00       |
|           | July 20, 1989   |              |                   |                 | 0           | 60           | 0.00 | 0.00       |
|           | July 5, 1990    |              |                   |                 | 0           | 54           | 0.00 | 0.00       |
|           | July 3, 1991    |              |                   |                 | 0           | 54           | 0.00 | 0.00       |
|           | July 3, 1992    |              |                   |                 | 0           | 54           | 0.00 | 0.00       |
| Skidway   | August 3, 1988  | Ov           | 28                | 26              | 54          | 160          | 0.34 | 0.34       |
|           | July 25, 1989   |              | 16                | 21              | 37          | 60           | 0.26 | 0.26       |
|           | July 13, 1990   |              | 2                 | 2               | 4           | 36           | 0.11 | 0.11       |
|           | August 7, 1991  |              | 16                | 17              | 33          | 54           | 0.61 | 0.61       |
|           | July 16, 1992   |              | 4                 | 6               | 10          | 54           | 0.19 | 0.19       |
|           | August 17, 1988 | Cb           | 448               | 485             | 933         | 179          | 5.21 | 6.40       |
|           | July 19, 1989   | Op           | 111               | 102             | 213         | 60           | 1.19 | 4.82       |
| Westward  | July 10, 1990   | Op           | 88                | 143             | 231         | 60           | 3.85 | 1.27       |
|           | July 17, 1991   | Cb           | 30                | 28              | 58          | 60           | 0.97 | 2.71       |
|           | July 14, 1992   | Op           | 17                | 23              | 40          | 54           | 0.67 | 3.00       |
|           | August 9, 1988  | Op           | 24                | 12              | 36          | 180          | 0.60 | 0.24       |
|           | August 7, 1989  | Op           | 35                | 49              | 84          | 60           | 1.56 | 0.10       |
|           | July 11, 1990   | Op           | 38                | 24              | 62          | 54           | 1.15 | 0.31       |
|           | August 1, 1991  | Cb           | 36                | 48              | 84          | 54           | 1.56 | 0.04       |
|           | July 3, 1992    | Op           | 52                | 26              | 78          | 54           | 1.44 | 0.07       |
|           | August 9, 1988  | Op           | 29                | 14              | 43          | 180          | 0.24 | 0.24       |
|           | August 7, 1989  | Op           | 4                 | 2               | 6           | 60           | 0.10 | 0.10       |
| Young     | July 11, 1990   |              | 2                 | 15              | 17          | 54           | 0.31 | 0.31       |
|           | August 1, 1991  |              | 2                 | 2               | 2           | 54           | 0.04 | 0.04       |
|           | July 3, 1992    |              | 2                 | 2               | 4           | 54           | 0.07 | 0.07       |

Species code: Cb = Cambarus bartoni; Op = Orconectes propinquus; Ov = Orconectes virilis

Table 4 Summary of Fish Species Inventory.\*

| Fish Taxon            | Species                     | Lake Name |    |    |    |    |    |    |    |    |    |    |    |    |    |
|-----------------------|-----------------------------|-----------|----|----|----|----|----|----|----|----|----|----|----|----|----|
|                       |                             | BC        | CL | CR | CN | DO | HR | HP | HY | PY | PC | PN | SK | WD | YG |
| Family Salmonidae     |                             |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Subfamily Salmoninae  |                             |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Salmoninae            | 80 Salvelinus fontinalis    |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Salmoninae            | 81 Salvelinus namaycush     |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Salmoninae            | 82 Hybrid                   |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Subfamily Coregoninae |                             |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Coregoninae           | 93 Coregonus artedii        |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Family Osmeridae      | 121 Osmerus mordax          |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Family Catostomidae   | 163 Catostomus commersoni   |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Family Cyprinidae     | 182 Phoxinus eos            |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 185 Coregonus plumbeus      |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 189 Hybognathus hankinsoni  |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 194 Notemigonus crysoleucas |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 198 Notropis cornutus       |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 199 Notropis heterodon      |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 200 Notropis heterolepis    |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 208 Pimephales notatus      |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 209 Pimephales promelas     |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 210 Rhinichthys atratulus   |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 212 Semotilus atromaculatus |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprinidae            | 214 Semotilus margarita     |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Family Ictaluridae    | 233 Ictalurus nebulosus     |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Family Catidae        | 271 Lota lota               |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Family Gasterosteidae | 281 Culaca inconstans       |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Family Centrarchidae  | 311 Ambloplites rupestris   |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Centrarchidae         | 313 Lepomis gibbosus        |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Centrarchidae         | 316 Micropterus dolomieu    |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Centrarchidae         | 317 Micropterus salmoides   |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Family Percidae       | 331 Perca flavescens        |           |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Percidae              | 338 Etheostoma exile        |           |    |    |    |    |    |    |    |    |    |    |    |    |    |

\* Data collected by MNR fish survey program

## Lakes

BC = Blue Chalk  
CL = Clear  
CR = Cradle  
CN = Crosson  
DO = Delano

HR = Hamer  
HP = Harp  
HY = Heney  
PY = Pearceley  
PC = Plastic

PN = Pincher  
SK = Skidway  
WD = Westward  
YG = Young

Table 5

Catch per unit effort summary of crayfish collected in the biomonitoring lakes, 1988 - 1992

| Lake by watershed                | Quarternary Watershed | Species Code | CPUE by year |       |       |       |      |
|----------------------------------|-----------------------|--------------|--------------|-------|-------|-------|------|
|                                  |                       |              | 1988         | 1989  | 1990  | 1991  | 1992 |
| 2EA Georgian Bay Tributaries     |                       |              |              |       |       |       |      |
| Pearceley *                      | 2EA19                 | Cb           |              |       | 0.40  | 0.17  | 0.00 |
| 2EB Moon River and Go Home River |                       |              |              |       |       |       |      |
| Skidway                          | 2EB02                 | Ov           | 0.34         | 0.26  | 0.11  | 0.61  | 0.19 |
| Hamer                            | 2EB05                 | Ov           | 0.43         | 1.23  | 0.61  | 0.81  | 0.65 |
| Young                            | 2EB07                 | Op           | 0.24         | 0.10  | 0.31  | 0.04  | 0.07 |
| Heney *                          | 2EB09                 | Ov           |              |       | 0.46  | 0.28  | 0.46 |
| Westward                         | 2EB11                 | Cb           | 5.18         | 4.02  | 0.65  | 1.55  | 1.56 |
|                                  |                       | Op           | 1.21         | 1.07  | 0.60  | 1.15  | 1.44 |
| Harp                             | 2EB13                 | Cb           | 0.12         | 0.07  | 0.00  | 0.00  | 0.00 |
|                                  |                       | Op           | 0.05         | 0.07  | 0.06  | 0.00  | 0.00 |
| Pincher                          | 2EB13                 | Cb           | 2.71         | 1.75  | 0.39  | 0.41  | 0.17 |
| 2EC Severn River                 |                       |              |              |       |       |       |      |
| Blue Chalk                       | 2EC15                 | Cb           | 0.98         | 0.75  | 0.33  | 0.63  | 0.46 |
|                                  |                       | Op           | 4.19         | 9.10  | 2.00  | 3.74  | 4.35 |
|                                  |                       | Ov           | 1.11         | 1.73  | 1.83  | 1.07  | 1.30 |
| Crosson                          | 2EC15                 | Cb           | 0.52         | 0.23  | 0.07  | 0.24  | 0.02 |
|                                  |                       | Ov           | 2.54         | 1.28  | 0.55  | 0.55  | 0.85 |
| 2HF Cameron Lake Drainage        |                       |              |              |       |       |       |      |
| Clear                            | 2HF08                 | Cb           | 0.97         | 1.48  | 2.33  | 0.55  | 0.53 |
|                                  |                       | Op           | 2.08         | 1.03  | 1.88  | 2.72  | 0.91 |
| Plastic                          | 2HF10                 |              | 0.00         | 0.00  | 0.00  | 0.00  | 0.00 |
| 2KD Upper Madawaska River        |                       |              |              |       |       |       |      |
| Delano                           | 2KD01                 | Cb           | 0.02         | 0.08  | 0.00  | 0.05  | 0.00 |
|                                  |                       | Op           | 0.88         | 1.03  | 0.42  | 0.72  | 0.91 |
|                                  |                       | Ov           | 0.01         | 0.02  | 0.00  | 0.00  | 0.00 |
| Cradle                           | 2KD18                 | Cb           | 12.68        | 17.70 | 10.17 | 16.50 | 7.15 |

Cb - *Cambarus bartoni*  
 Op - *Orconectes propinquus*  
 Ov - *Orconectes virilis*

\* Heney and Pearceley lakes were not sampled prior to 1990

Table 7 Presence/absence of crayfish species over the period 1988 - 1992.

| Lake Name  | Cambarus bartoni |      |      |      |      | Orconectes propinquus |      |      |      |      | Orconectes virilis |      |      |      |      |
|------------|------------------|------|------|------|------|-----------------------|------|------|------|------|--------------------|------|------|------|------|
|            | 1988             | 1989 | 1990 | 1991 | 1992 | 1988                  | 1989 | 1990 | 1991 | 1992 | 1988               | 1989 | 1990 | 1991 | 1992 |
| Blue Chalk | P                | P    | P    | P    | P    | P                     | P    | P    | P    | P    | P                  | P    | P    | P    | P    |
| Clear      | P                | P    | P    | P    | P    | P                     | P    | P    | P    | P    | .                  | .    | .    | .    | .    |
| Cradle     | P                | P    | P    | P    | P    | .                     | .    | .    | .    | .    | .                  | .    | .    | .    | .    |
| Crosson    | P                | P    | P    | P    | P    | .                     | .    | .    | .    | .    | P                  | P    | P    | P    | P    |
| Delano     | P                | P    | A    | P    | A    | P                     | P    | P    | P    | P    | P                  | P    | A    | A    | A    |
| Hamer      | .                | .    | .    | .    | .    | .                     | .    | .    | .    | .    | P                  | P    | P    | P    | P    |
| Harp       | P                | P    | A    | A    | A    | P                     | P    | P    | A    | A    | .                  | .    | .    | .    | .    |
| Heney      | *                | *    | .    | .    | .    | *                     | *    | .    | .    | .    | *                  | *    | P    | P    | P    |
| Pearceley  | *                | *    | P    | P    | A    | *                     | *    | .    | .    | .    | *                  | *    | .    | .    | .    |
| Pincher    | P                | P    | P    | P    | P    | .                     | .    | .    | .    | .    | .                  | .    | .    | .    | .    |
| Skidway    | .                | .    | .    | .    | .    | .                     | .    | .    | .    | .    | P                  | P    | P    | P    | P    |
| Westward   | P                | P    | P    | P    | P    | P                     | P    | P    | P    | P    | .                  | .    | .    | .    | .    |
| Young      | .                | .    | .    | .    | .    | P                     | P    | P    | P    | P    | .                  | .    | .    | .    | .    |

\* not sampled

. species never captured in lake during 5 year period

**Table 8** Percentages of male and female crayfish by species in the trap catches from 1988 - 1992.

| Species           | Year                        | Female Catch |        | Male Catch |        | Total Catch |
|-------------------|-----------------------------|--------------|--------|------------|--------|-------------|
|                   |                             | Percentage   | Number | Percentage | Number |             |
| <u>Cambarus</u>   | 1988                        | 49%          | (2009) | 51%        | (2064) | 4073        |
| <u>bartoni</u>    | 1989                        | 45%          | (705)  | 55%        | (845)  | 1550        |
|                   | 1990                        | 33%          | (102)  | 67%        | (204)  | 306         |
|                   | 1991                        | 42%          | (205)  | 58%        | (288)  | 493         |
|                   | 1992                        | 36%          | (188)  | 64%        | (338)  | 526         |
|                   | overall mean<br>(1988-1992) | 41%          |        | 59%        |        |             |
| <u>Orconectes</u> | 1988                        | 52%          | (776)  | 48%        | (713)  | 1489        |
| <u>propinquus</u> | 1989                        | 49%          | (374)  | 51%        | (387)  | 761         |
|                   | 1990                        | 49%          | (69)   | 51%        | (71)   | 140         |
|                   | 1991                        | 49%          | (221)  | 51%        | (231)  | 452         |
|                   | 1992                        | 56%          | (233)  | 44%        | (181)  | 414         |
|                   | overall mean<br>(1988-1992) | 51%          |        | 49%        |        |             |
| <u>Orconectes</u> | 1988                        | 45%          | (317)  | 55%        | (381)  | 698         |
| <u>virilis</u>    | 1989                        | 35%          | (103)  | 65%        | (190)  | 293         |
|                   | 1990                        | 29%          | (33)   | 71%        | (79)   | 112         |
|                   | 1991                        | 39%          | (71)   | 61%        | (109)  | 180         |
|                   | 1992                        | 50%          | (93)   | 50%        | (93)   | 186         |
|                   | overall mean<br>(1988-1992) | 40%          |        | 60%        |        |             |



Figure 1 Location of the study lakes.

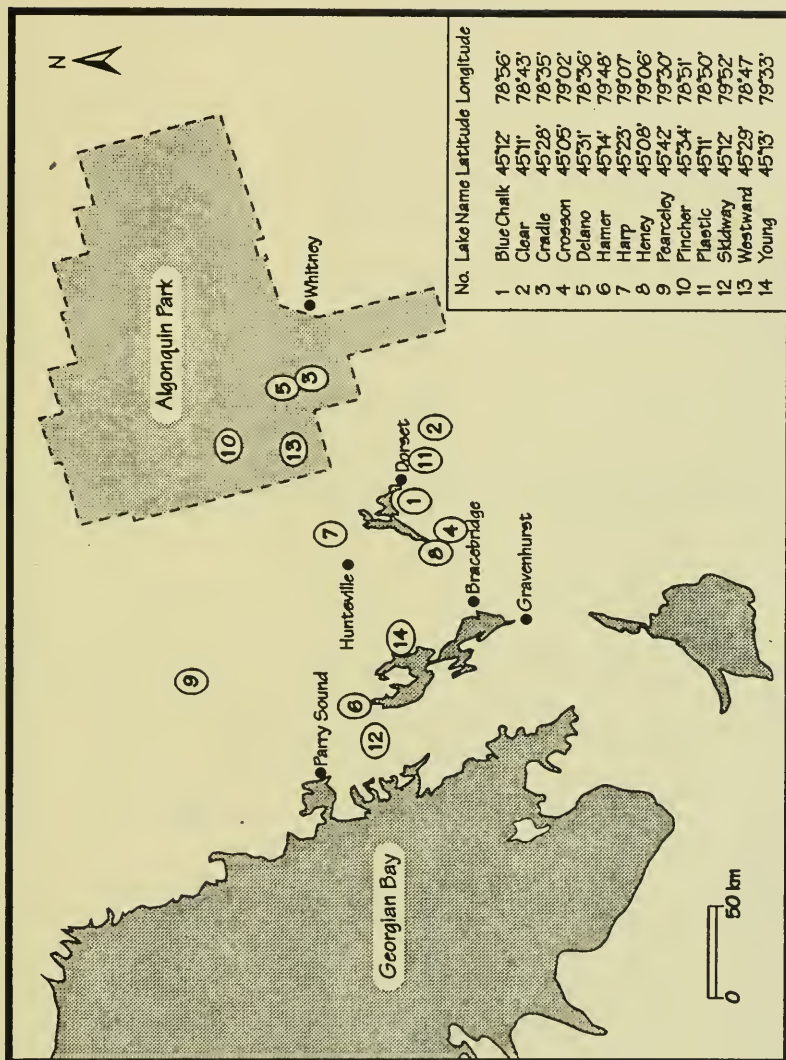


Figure 2 Temporal trends in aluminum concentrations in Blue Chalk, Crosson, Clear and Cradle lakes (mean  $\pm$  1 SE).

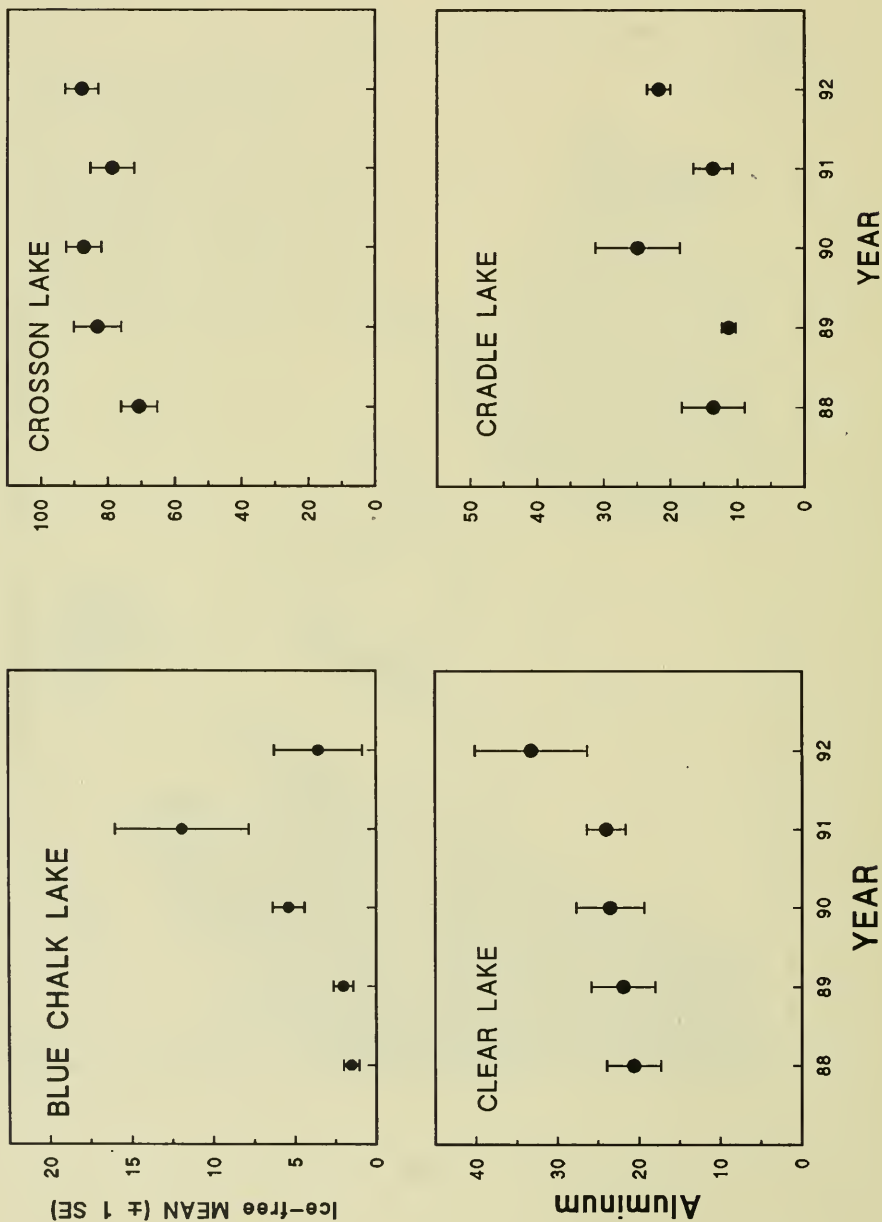


Figure 3 Temporal trends in aluminum concentrations in Delano, Harp, Hamer and Heney lakes (mean  $\pm$  1 SE).

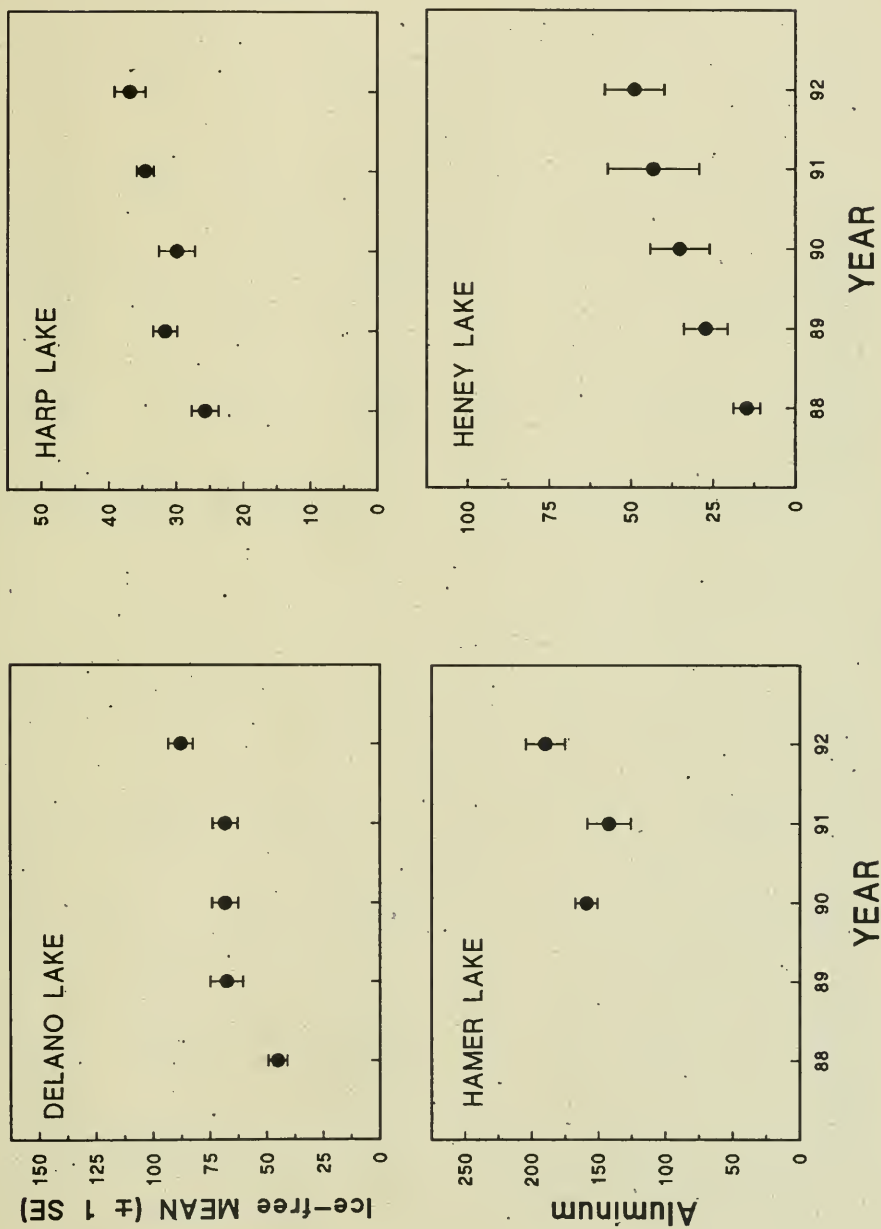


Figure 4 Temporal trends in aluminum concentrations in Pearceley, Pincher, Plastic and Skidway lakes (mean  $\pm$  1 SE).

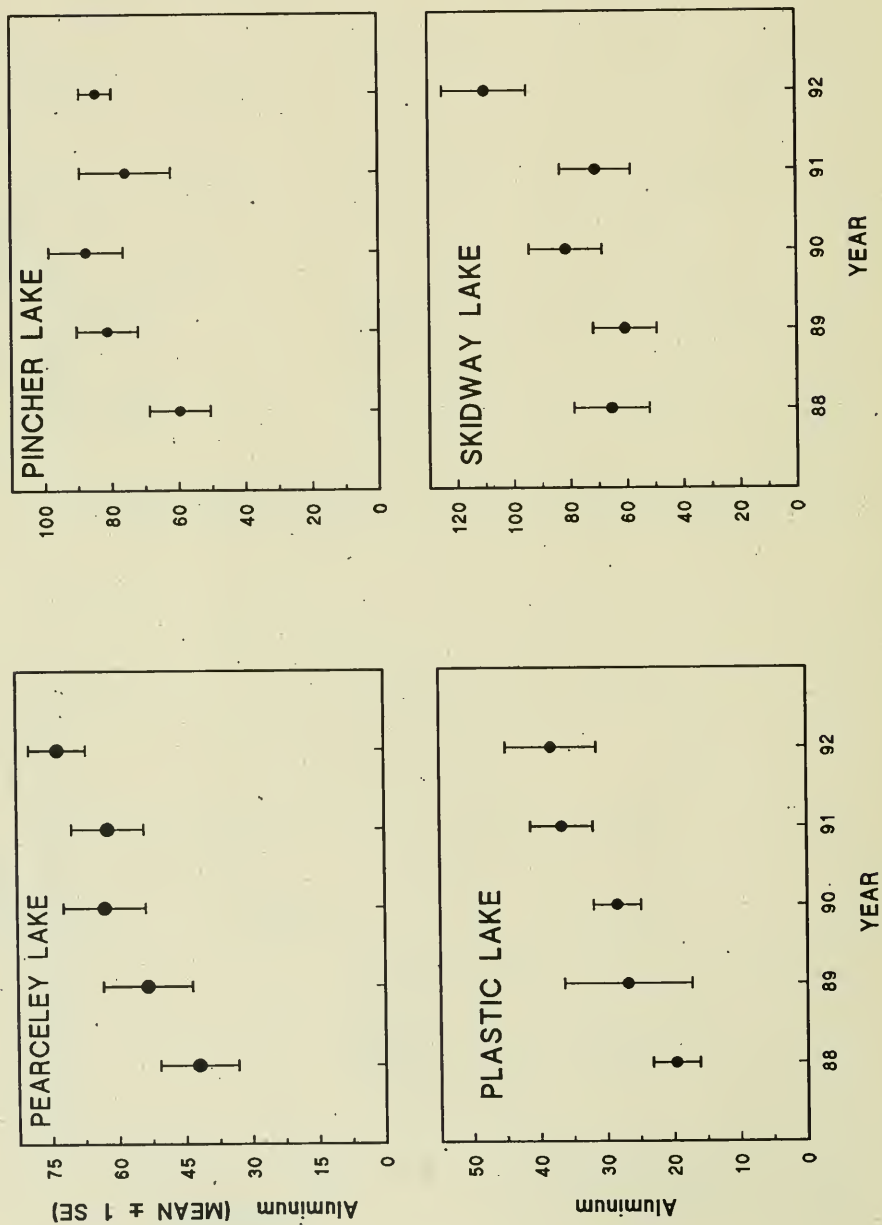


Figure 5 Temporal trends in aluminum concentrations in Westward and Young lakes (mean  $\pm$  1 SE).

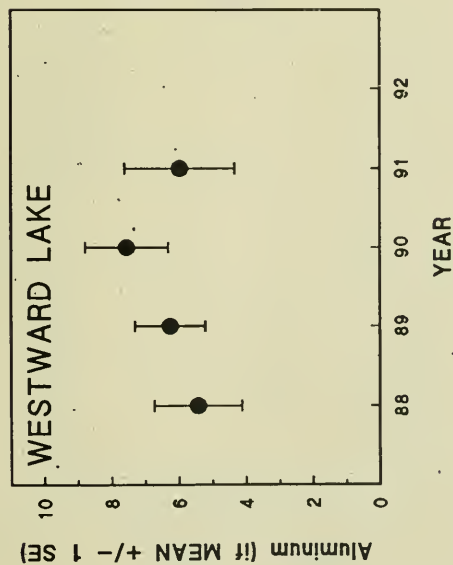
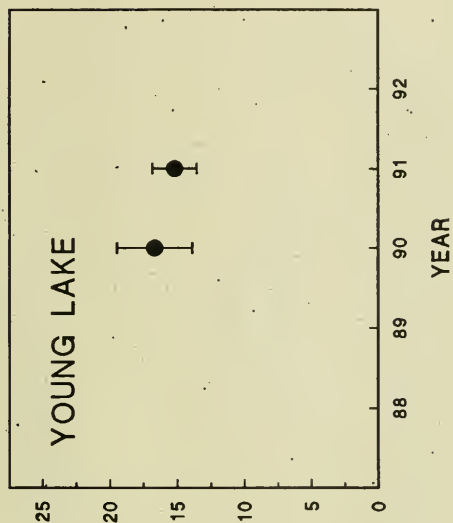


Figure 6 Temporal trends in crayfish CPUE for Blue Chalk, Clear, Cradle and Crosson lakes.

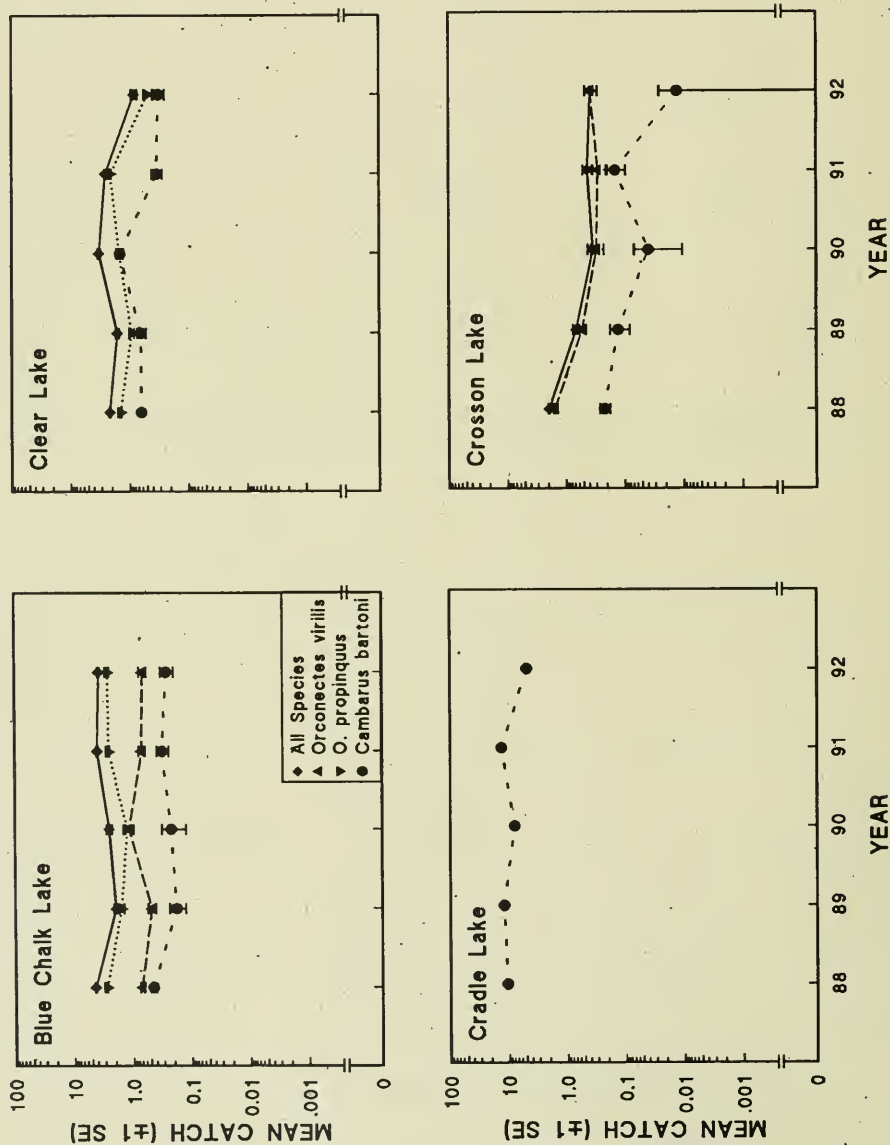


Figure 7 Temporal trends in crayfish CPUE for Delano, Harp, Hamer and Heney lakes.

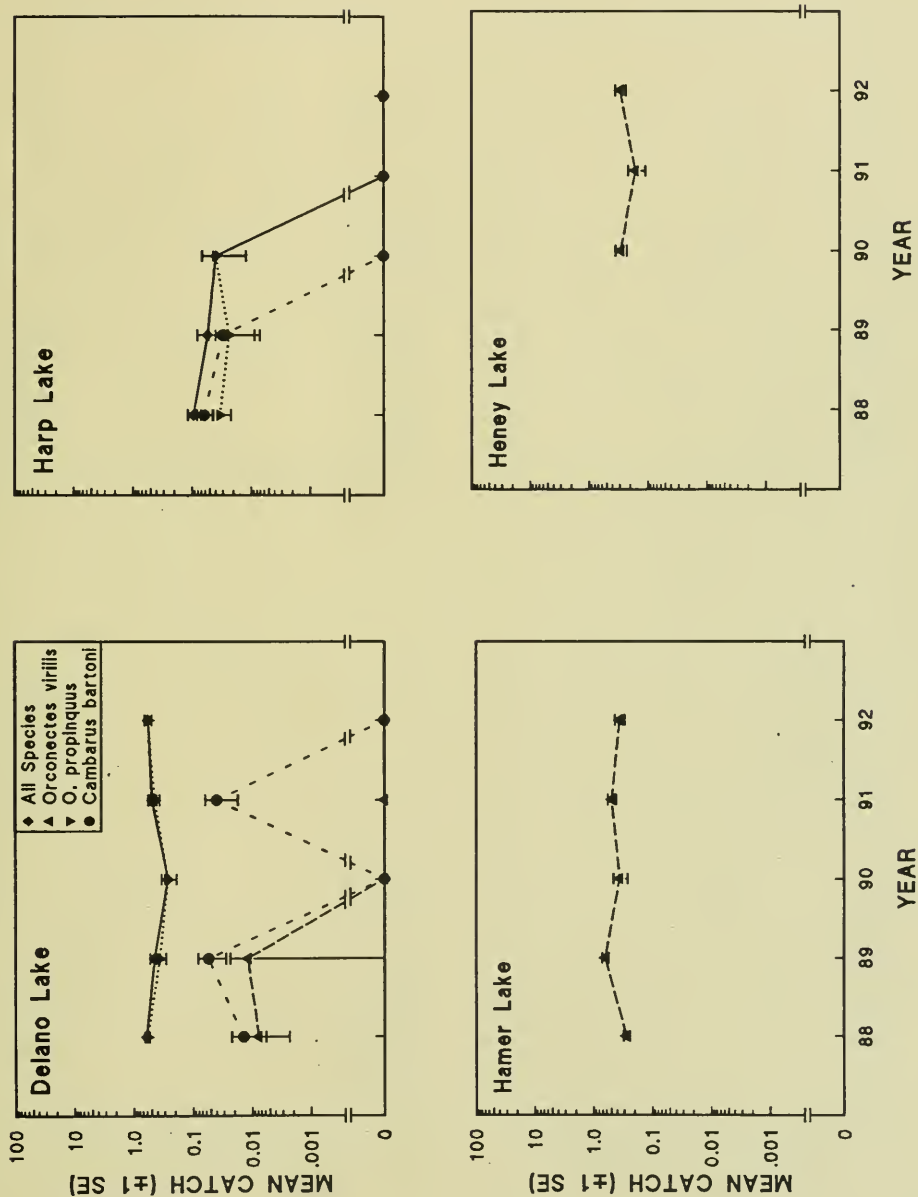


Figure 8 Temporal trends in crayfish CPUE for Pearceleley, Pincher, Plastic and Skidway lakes.

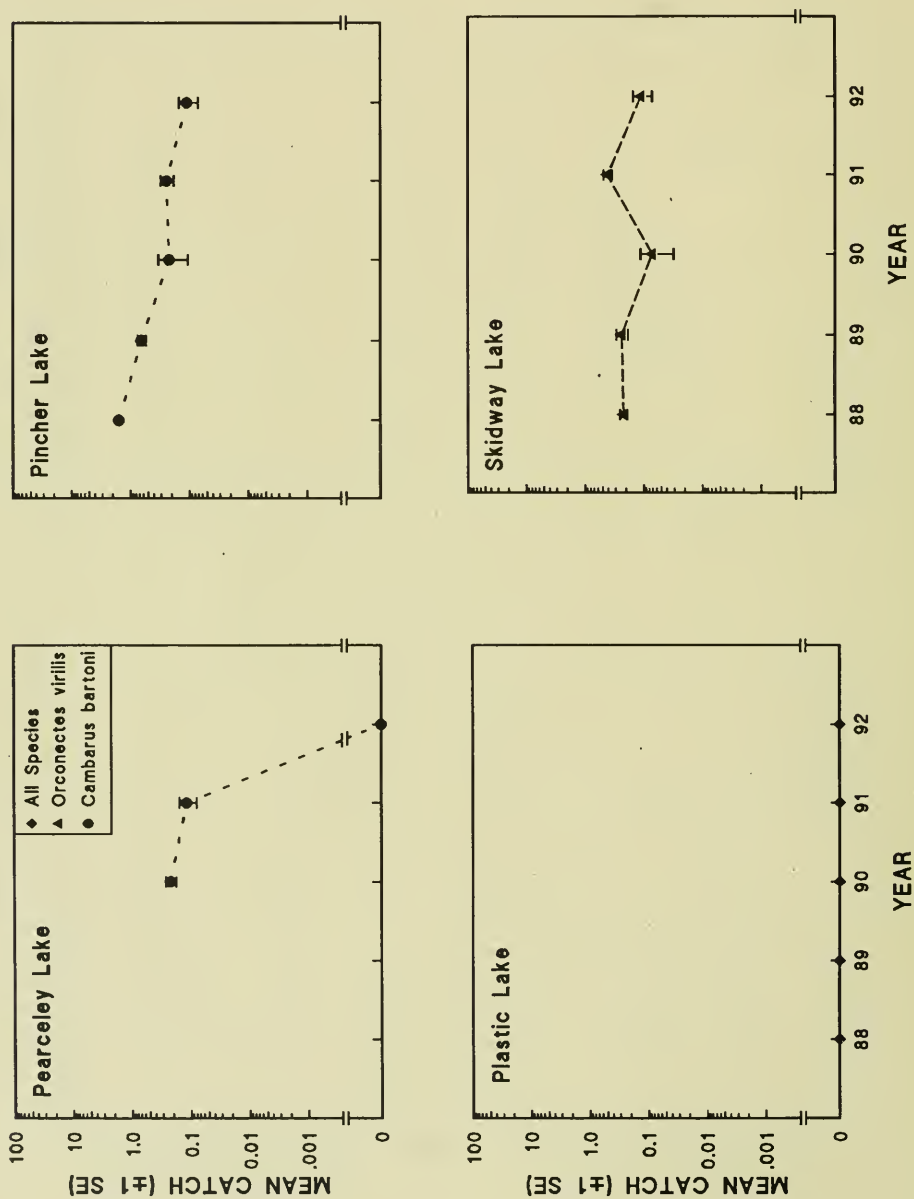


Figure 9 Temporal trends in crayfish CPUE for Westward and Young lakes.

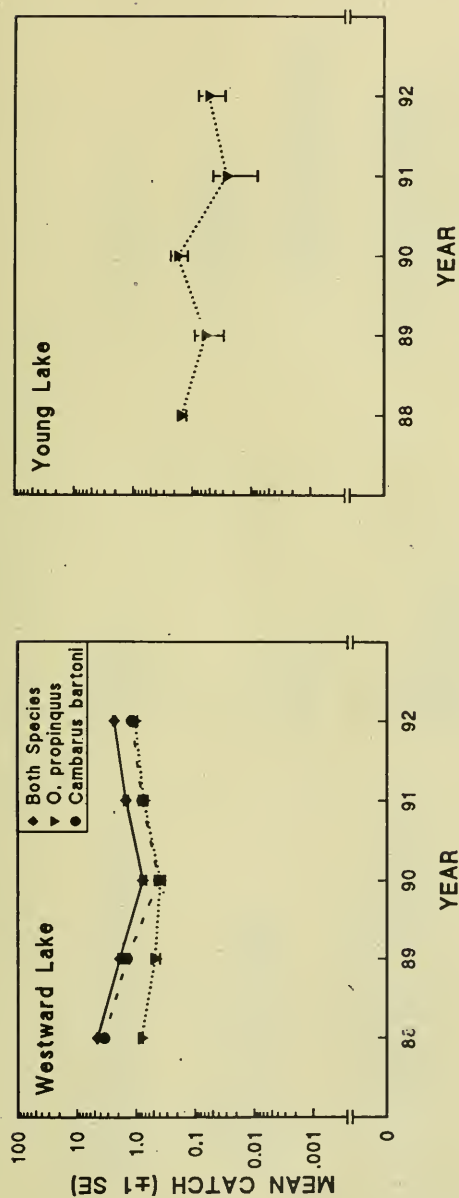
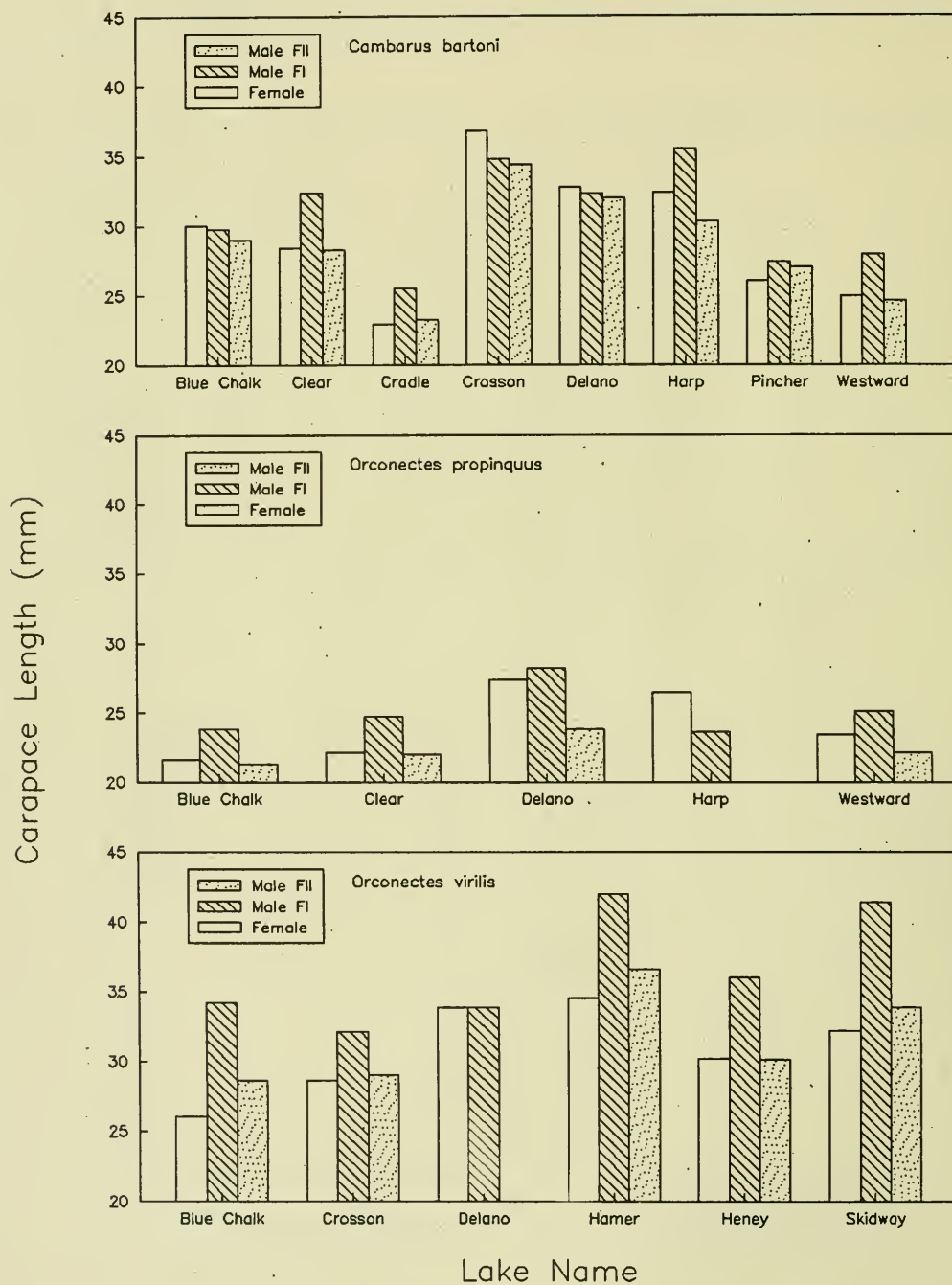
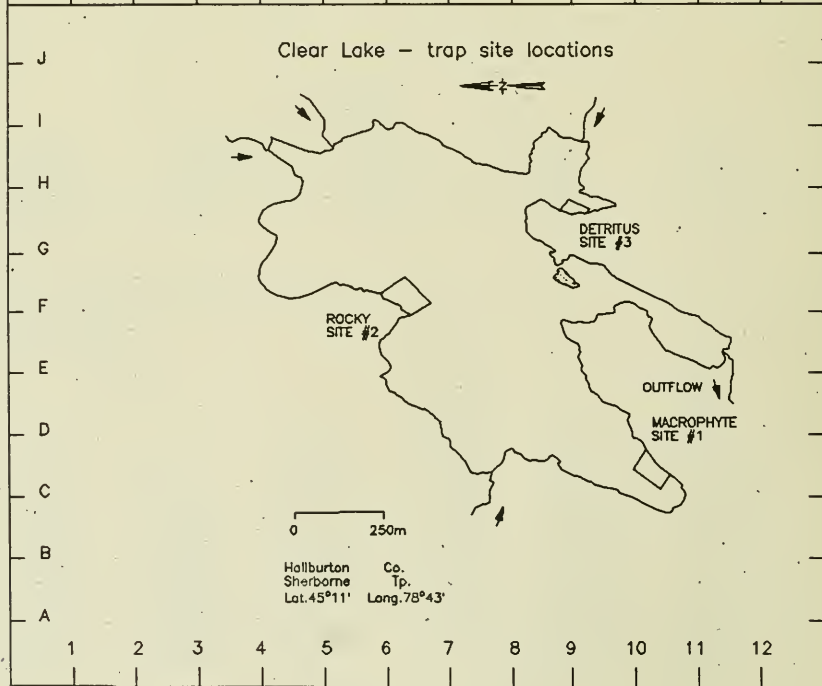
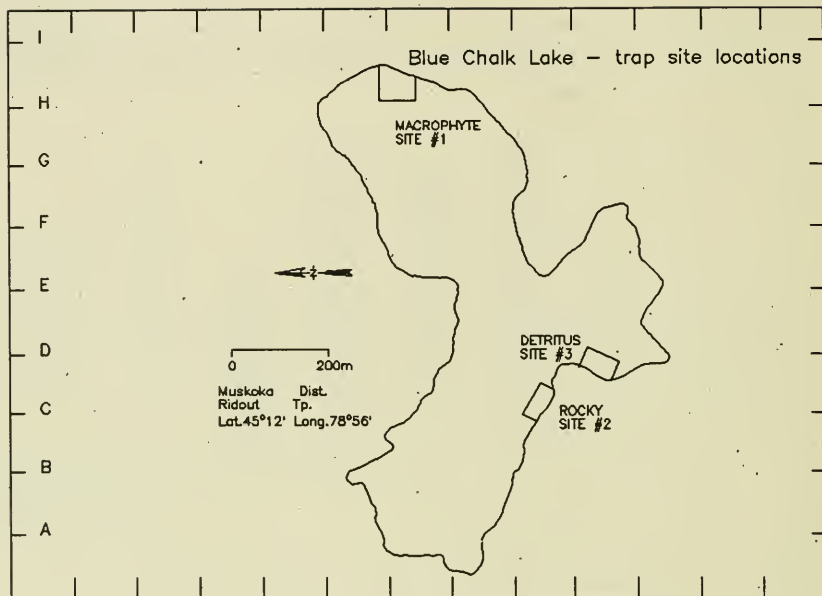


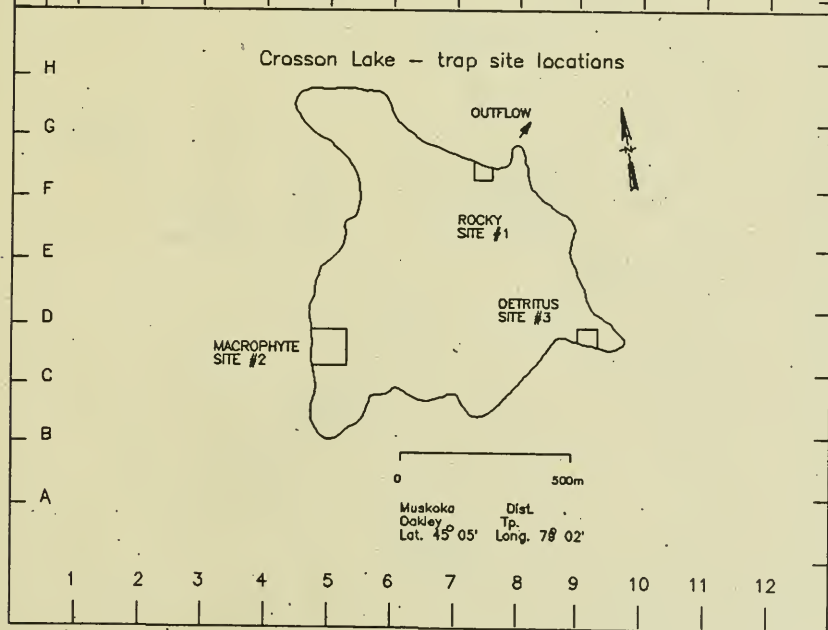
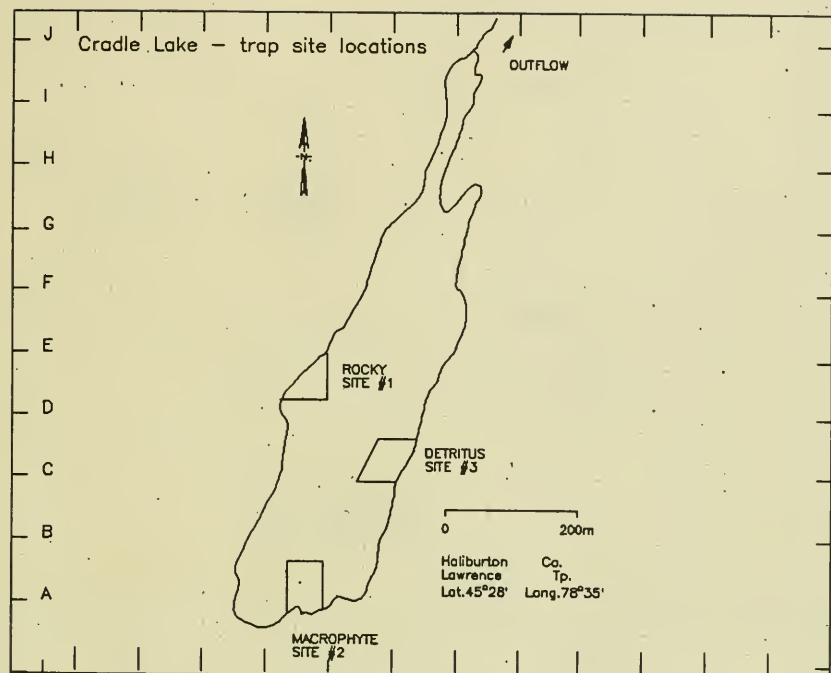
Figure 10 Mean carapace lengths of the crayfish catch by species for the period 1988-1992.

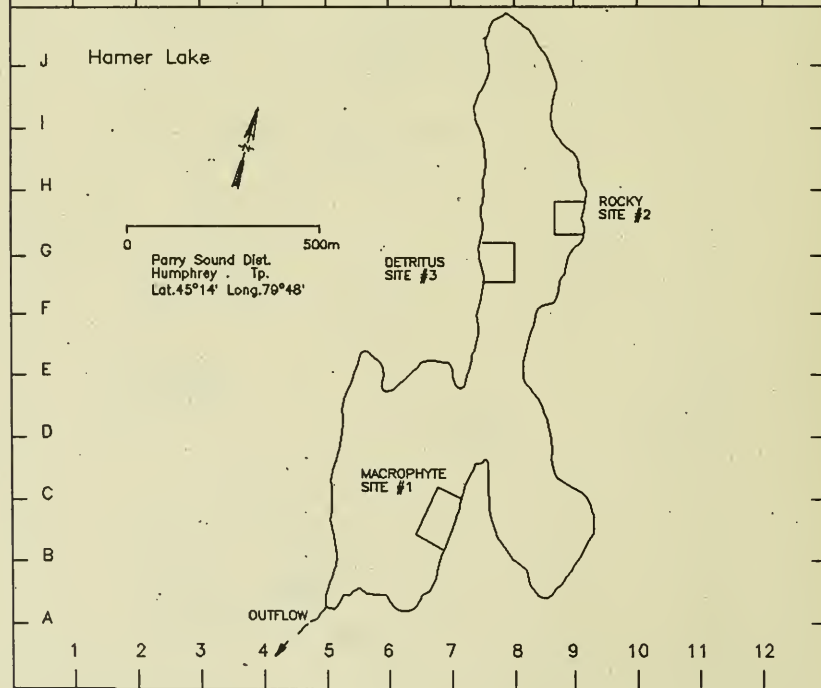
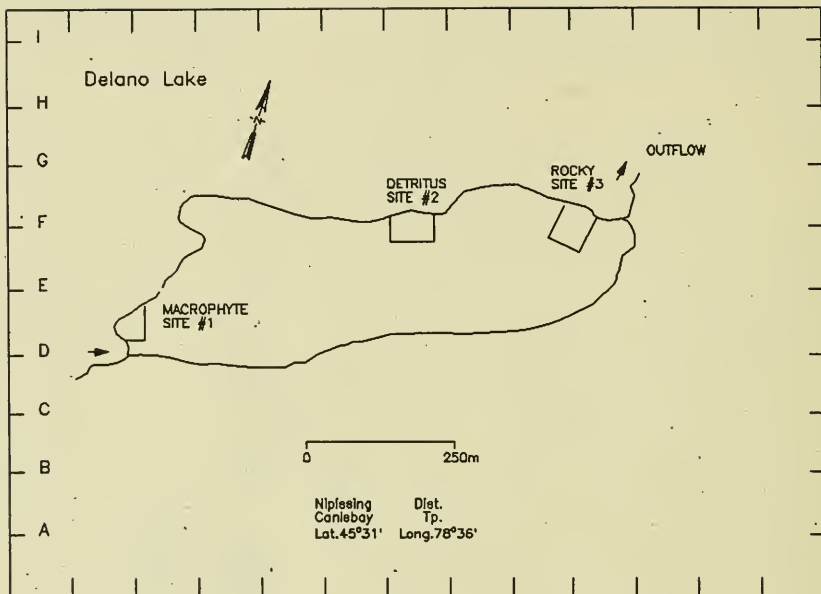


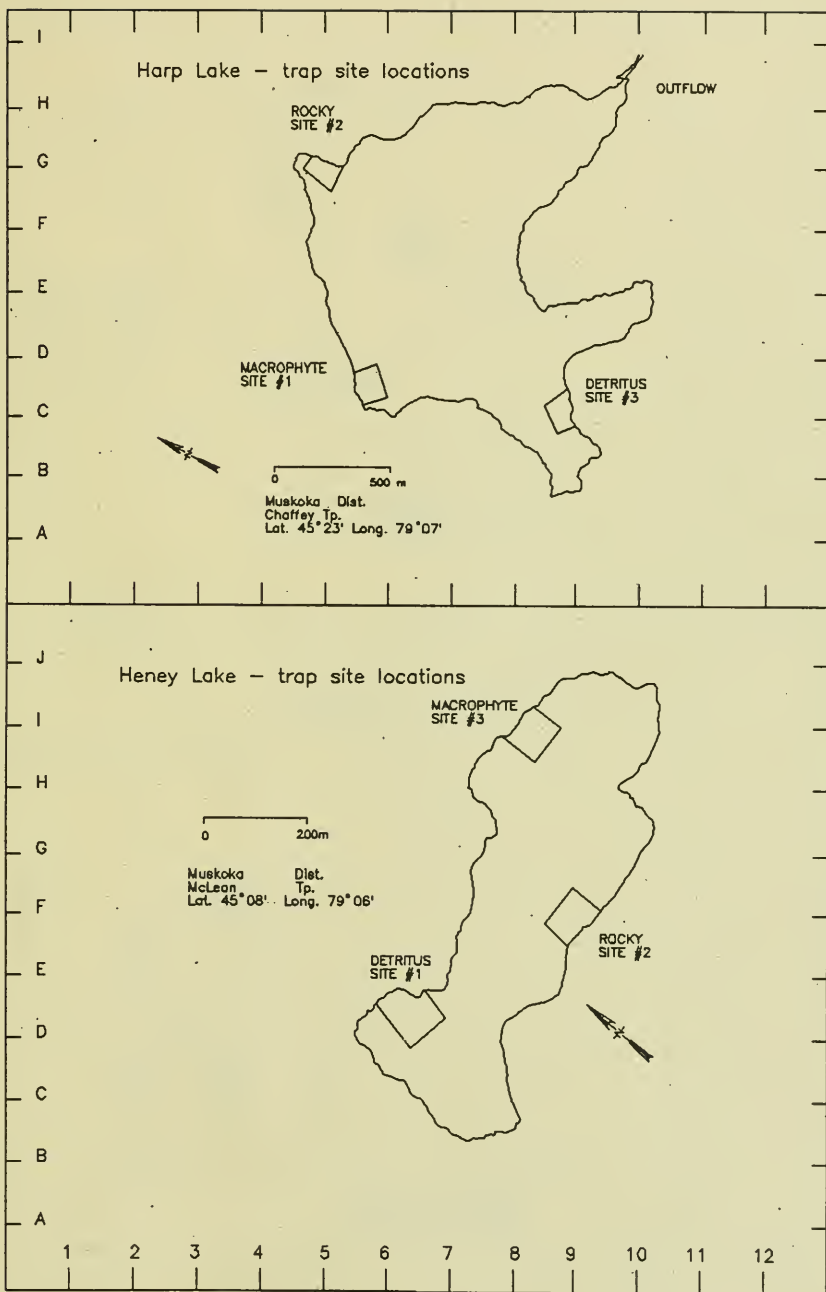
## Appendix 1

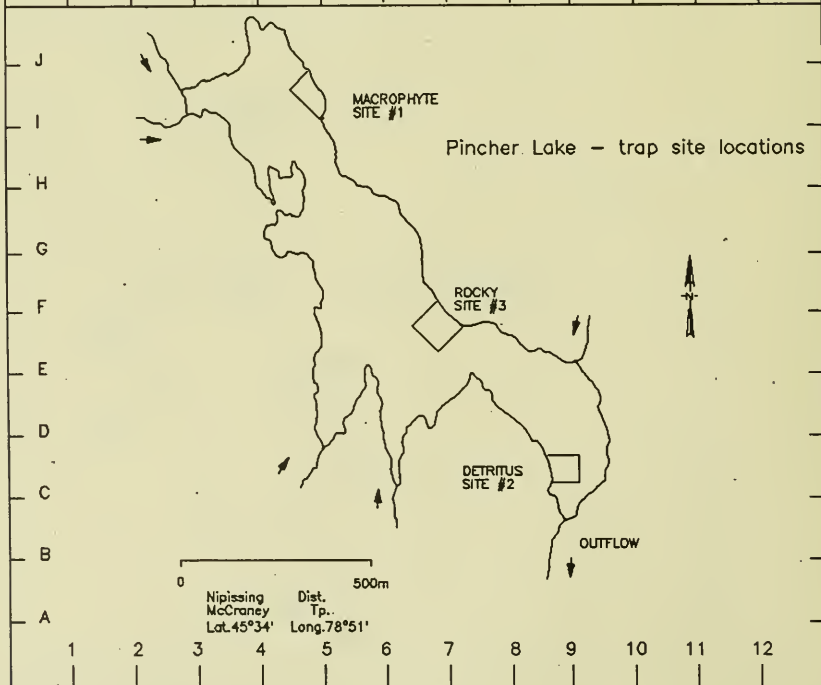
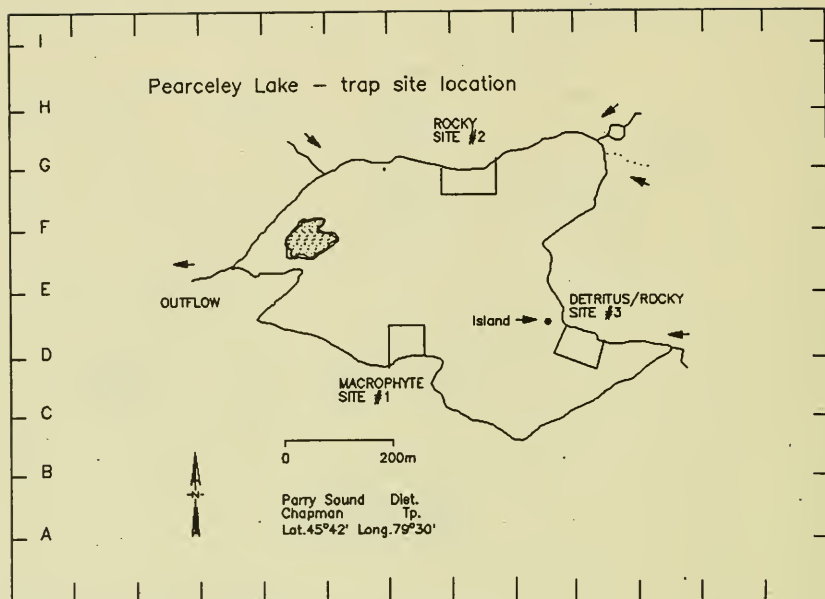
Maps of the study lakes illustrating the locations of the three sampling sites

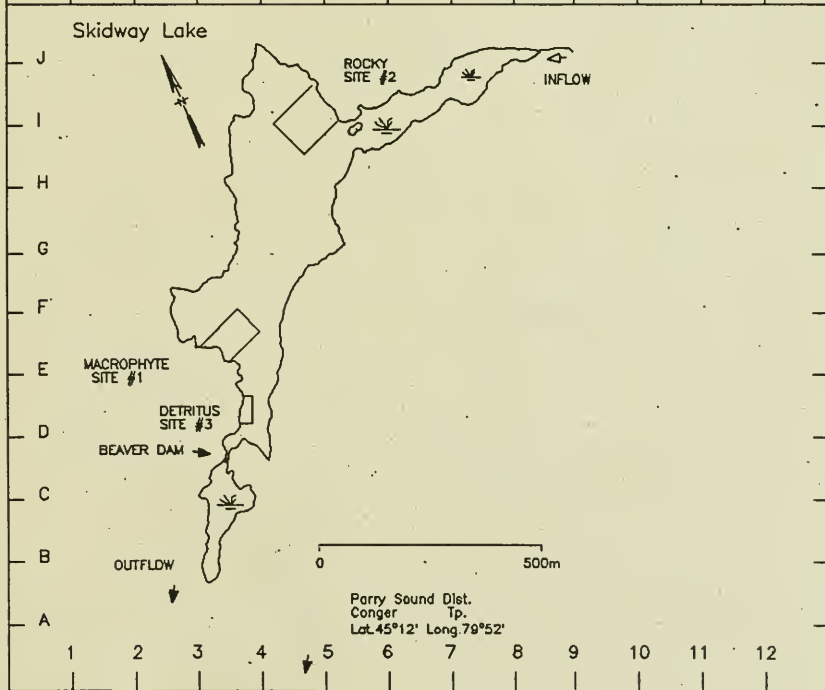
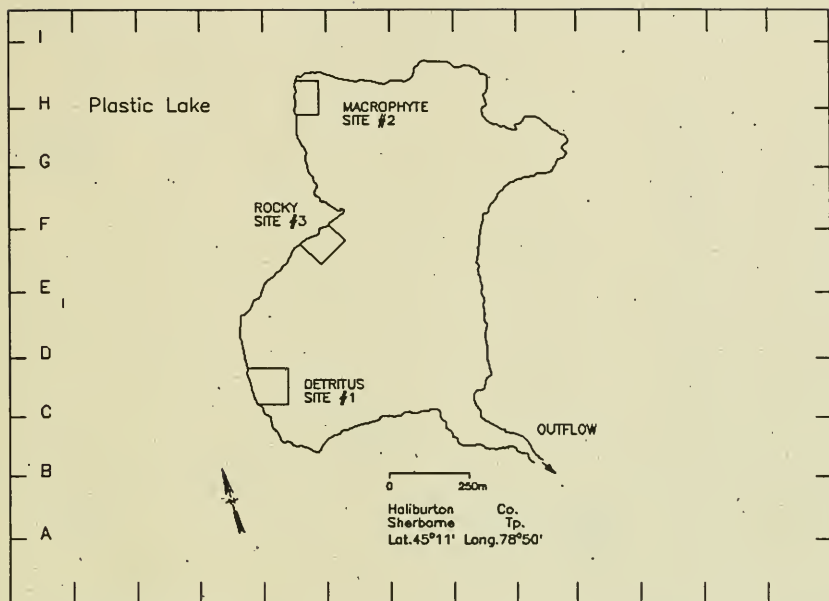


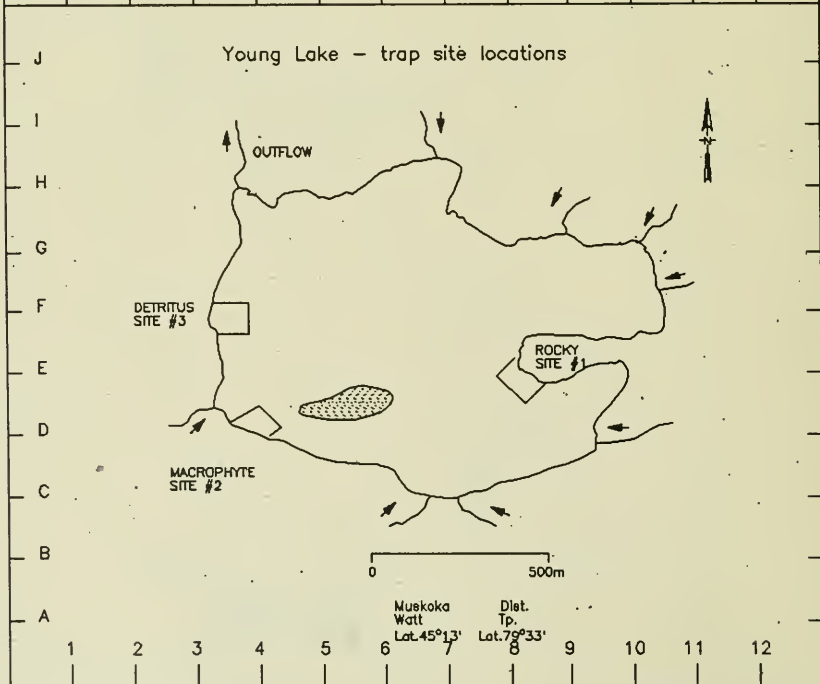
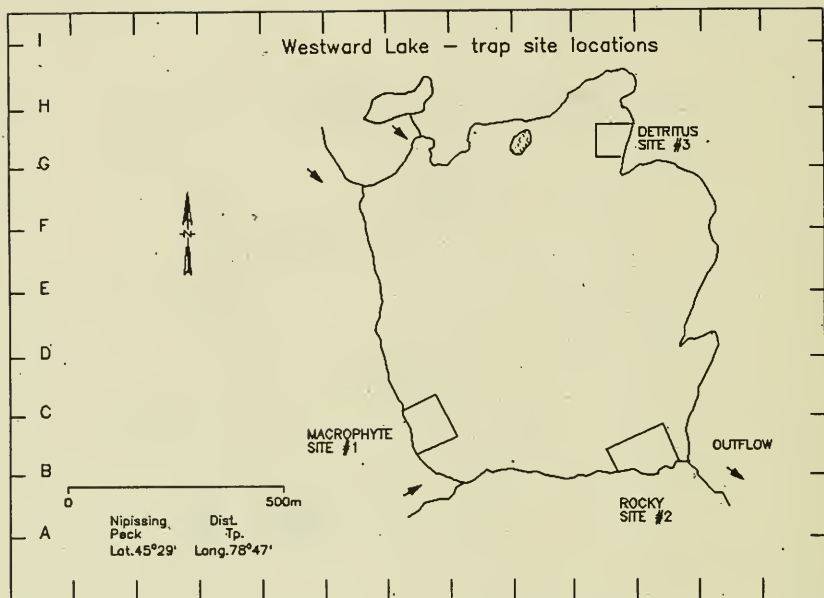












## Appendix 2

### Description of chemical parameters

Appendix 2      Description of chemical parameters.

| Parameter                                          | Abbreviation    | Description                            |
|----------------------------------------------------|-----------------|----------------------------------------|
| Alkalinity (mg • L <sup>-1</sup> )                 | alkti           | Total inflection point alkalinity      |
| Alkalinity (mg • L <sup>-1</sup> )                 | alkt            | Total fixed point alkalinity to pH 4.5 |
| Alkalinity (mg • L <sup>-1</sup> )                 | alkt3           | Total fixed point alkalinity to pH 3.8 |
| Aluminum (μg • L <sup>-1</sup> )                   | alut            | Total Aluminum unfiltered              |
| Calcium (mg • L <sup>-1</sup> )                    | caur            | Calcium unfiltered reactive            |
| Chloride (mg • L <sup>-1</sup> )                   | clidur          | Chloride ulfiltered reactive           |
| Conductivity (μS)                                  | cond25          | Conductivity at 25°C                   |
| Dissolved Inorganic Carbon (mg • L <sup>-1</sup> ) | DIC             | Dissolved Inorganic Carbon             |
| Dissolved Organic Carbon (mg • L <sup>-1</sup> )   | DOC             | Dissolved Organic Carbon               |
| Iron (μg • L <sup>-1</sup> )                       | Fe              | Total Iron                             |
| Potassium (mg • L <sup>-1</sup> )                  | K               | Total Potassium                        |
| Magnesium (mg • L <sup>-1</sup> )                  | Mg              | Magnesium                              |
| Manganese (μg • L <sup>-1</sup> )                  | MN              | Manganese                              |
| Sodium (mg)                                        | NA              | Sodium                                 |
| Ammonium (μg • L <sup>-1</sup> )                   | NH <sub>4</sub> | Ammonium                               |
| Nitrate-Nitrite (μg • L <sup>-1</sup> )            | NO <sub>3</sub> | Nitrate-Nitrite                        |
| Total Kjeldahl Nitrogen (μg • L <sup>-1</sup> )    | TKN             | Total Kjeldahl Nitrogen                |
| pH                                                 | pH              | pH                                     |
| Sulphate (mg • L <sup>-1</sup> )                   | SO <sub>4</sub> | Sulphate as SO <sub>4</sub>            |
| Total Phosphorus (μg)                              | TP              | Total Phosphorus as P                  |

### Appendix 3

Chemical parameters for the fourteen study lakes over the period 1988-1992

## Blue Chalk

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD    | SE    | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|--------|-------|--------|--------|
| Alkti     | 4.35   | 4.25   | 4.51   | 4.48   | 4.47   | 4.41   | 0.122  | 0.055 | 4.51   | 4.25   |
| Alkt      | 6.06   | 6.03   | 6.19   | 6.21   | 6.10   | 6.12   | 0.088  | 0.040 | 6.21   | 6.03   |
| Al        | 1.58   | 4.59   | 5.53   | 9.96   | 3.55   | 5.04   | 3.484  | 1.558 | 9.96   | 1.58   |
| Ca        | 2.59   | 2.61   | 2.5    | 2.61   | 2.53   | 2.57   | 0.057  | 0.025 | 2.61   | 2.50   |
| Cl-       | 0.37   | 0.39   | 0.41   | 0.41   | 0.42   | 0.40   | 0.021  | 0.009 | 0.42   | 0.37   |
| Cond25    | 28.24  | 28.49  | 28.63  | 27.89  | 28.67  | 28.38  | 0.361  | 0.161 | 28.67  | 27.89  |
| DIC       | 1.45   | 1.47   | 1.53   | 1.42   | 1.43   | 1.46   | 0.048  | 0.022 | 1.53   | 1.42   |
| DOC       | 1.63   | 1.77   | 1.77   | 1.81   | 1.75   | 1.75   | 0.076  | 0.034 | 1.81   | 1.63   |
| Fe        | 63.19  | 51.79  | 89.7   | 60.51  | 47.00  | 62.44  | 18.534 | 8.289 | 89.70  | 47.00  |
| K         | 0.38   | 0.39   | 0.38   | 0.38   | 0.38   | 0.38   | 0.005  | 0.002 | 0.39   | 0.38   |
| Mg        | 0.79   | 0.76   | 0.74   | 0.76   | 0.74   | 0.76   | 0.023  | 0.010 | 0.79   | 0.74   |
| Mn        | 26     | 29.73  | 38.39  | 29.58  | 31.90  | 31.12  | 5.123  | 2.291 | 38.39  | 26.00  |
| Na        | 0.8    | 0.79   | 0.8    | 0.79   | 0.78   | 0.79   | 0.008  | 0.004 | 0.80   | 0.78   |
| NH4       | 27.35  | 19.48  | 20.28  | 17.65  | 27.71  | 22.49  | 5.252  | 2.349 | 27.71  | 17.65  |
| NO3       | 31.79  | 26.95  | 12.66  | 15.36  | 21.68  | 21.69  | 8.862  | 3.963 | 31.79  | 12.66  |
| TKN       | 183.81 | 192.73 | 194.73 | 175.35 | 176.97 | 184.72 | 9.890  | 4.423 | 194.73 | 175.35 |
| pH        | 6.73   | 6.63   | 6.63   | 6.73   | 6.71   | 6.69   | 0.058  | 0.026 | 6.73   | 6.63   |
| SO4       | 6.4    | 6.26   | 6.21   | 6.32   | 6.15   | 6.27   | 0.107  | 0.048 | 6.40   | 6.15   |
| Total P   | 5.53   | 5.61   | 5.84   | 5.53   | 5.69   | 5.64   | 0.145  | 0.065 | 5.84   | 5.53   |

## Clear

| Parameter | 1988   | 1989  | 1990   | 1991   | 1992   | MEAN   | STD    | SE    | MAX    | MIN    |
|-----------|--------|-------|--------|--------|--------|--------|--------|-------|--------|--------|
| Alkti     | 0.36   | 0.42  | 0.43   | 0.42   | 0.40   | 0.41   | 0.031  | 0.014 | 0.43   | 0.36   |
| Alkt      | 2.05   | 2.19  | 2.16   | 2.29   | 2.16   | 2.17   | 0.096  | 0.043 | 2.29   | 2.05   |
| Al        | 19.28  | 21.57 | 22.52  | 24.01  | 33.20  | 24.12  | 5.993  | 2.680 | 33.20  | 19.28  |
| Ca        | 2.31   | 2.38  | 2.19   | 2.23   | 2.13   | 2.25   | 0.110  | 0.049 | 2.38   | 2.13   |
| Cl-       | 0.41   | 0.42  | 0.44   | 0.43   | 0.44   | 0.43   | 0.014  | 0.006 | 0.44   | 0.41   |
| Cond25    | 25.59  | 25.67 | 25.64  | 24.67  | 25.33  | 25.38  | 0.469  | 0.210 | 25.67  | 24.67  |
| DIC       | 0.52   | 0.52  | 0.73   | 0.53   | 0.76   | 0.61   | 0.137  | 0.061 | 0.76   | 0.52   |
| DOC       | 1.43   | 1.52  | 1.59   | 1.86   | 1.63   | 1.61   | 0.180  | 0.080 | 1.86   | 1.43   |
| Fe        | 47.92  | 20.15 | 26.27  | 24.68  | 24.00  | 28.60  | 12.332 | 5.515 | 47.92  | 20.15  |
| K         | 0.35   | 0.35  | 0.36   | 0.35   | 0.35   | 0.35   | 0.006  | 0.003 | 0.36   | 0.35   |
| Mg        | 0.56   | 0.56  | 0.56   | 0.55   | 0.52   | 0.55   | 0.019  | 0.008 | 0.56   | 0.52   |
| Mn        | 42.92  | 47.9  | 44.58  | 43.77  | 45.00  | 44.83  | 2.113  | 0.945 | 47.90  | 42.92  |
| Na        | 0.48   | 0.49  | 0.5    | 0.48   | 0.48   | 0.49   | 0.010  | 0.005 | 0.50   | 0.48   |
| NH4       | 17.99  | 14.82 | 12.04  | 8.48   | 24.18  | 15.50  | 6.689  | 2.992 | 24.18  | 8.48   |
| NO3       | 18.91  | 22.23 | 15     | 10.05  | 23.32  | 17.90  | 6.102  | 2.729 | 23.32  | 10.05  |
| TKN       | 149.63 | 143.6 | 167.87 | 152.92 | 149.86 | 152.78 | 10.162 | 4.544 | 167.87 | 143.60 |
| pH        | 5.79   | 5.81  | 5.79   | 5.84   | 5.73   | 5.79   | 0.046  | 0.021 | 5.84   | 5.73   |
| SO4       | 8.01   | 7.8   | 7.66   | 7.63   | 7.88   | 7.80   | 0.176  | 0.079 | 8.01   | 7.63   |
| Total P   | 3.52   | 3.45  | 3.52   | 3.45   | 4.35   | 3.66   | 0.433  | 0.194 | 4.35   | 3.45   |

## Cradle

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD    | SE     | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Alkti     | 0.31   | 0.64   | 0.43   | 0.47   | 0.27   | 0.42   | 0.163  | 0.073  | 0.64   | 0.27   |
| Alkt      | 2.06   | 2.28   | 2.17   | 2.28   | 2.01   | 2.16   | 0.140  | 0.063  | 2.28   | 2.01   |
| Al        | 13.6   | 11.15  | 23.63  | 13.65  | 21.75  | 16.76  | 6.206  | 2.775  | 23.63  | 11.15  |
| Ca        | 1.83   | 1.91   | 1.77   | 1.88   | 1.80   | 1.84   | 0.064  | 0.029  | 1.91   | 1.77   |
| Cl-       | 0.32   | 0.32   | 0.33   | 0.34   | 0.34   | 0.33   | 0.010  | 0.005  | 0.34   | 0.32   |
| Cond25    | 21.9   | 22     | 22.37  | 21.97  | 22.31  | 22.11  | 0.239  | 0.107  | 22.37  | 21.90  |
| DIC       | 0.64   | 0.72   | 0.76   | 0.6    | 0.63   | 0.67   | 0.075  | 0.034  | 0.76   | 0.60   |
| DOC       | 1.39   | 1.53   | 1.54   | 1.64   | 1.44   | 1.51   | 0.108  | 0.048  | 1.64   | 1.39   |
| Fe        | 96.23  | 117.56 | 113.71 | 78.14  | 56.00  | 92.33  | 28.669 | 12.821 | 117.56 | 56.00  |
| K         | 0.3    | 0.3    | 0.3    | 0.3    | 0.28   | 0.30   | 0.008  | 0.004  | 0.30   | 0.28   |
| Mg        | 0.5    | 0.48   | 0.47   | 0.49   | 0.47   | 0.48   | 0.016  | 0.007  | 0.50   | 0.47   |
| Mn        | 33.6   | 36.05  | 33.24  | 30.96  | 31.00  | 32.97  | 2.364  | 1.057  | 36.05  | 30.96  |
| Na        | 0.46   | 0.45   | 0.46   | 0.45   | 0.46   | 0.46   | 0.006  | 0.003  | 0.46   | 0.45   |
| NH4       | 24.39  | 25.36  | 23.74  | 24.61  | 18.36  | 23.29  | 3.151  | 1.409  | 25.36  | 18.36  |
| NO3       | 18.08  | 11.68  | 18.26  | 3.85   | 29.55  | 16.28  | 10.591 | 4.737  | 29.55  | 3.85   |
| TKN       | 167.53 | 176.43 | 179.32 | 170.19 | 167.91 | 172.28 | 5.938  | 2.656  | 179.32 | 167.53 |
| pH        | 5.82   | 5.78   | 5.71   | 5.82   | 5.56   | 5.74   | 0.123  | 0.055  | 5.82   | 5.56   |
| SO4       | 6.69   | 6.58   | 6.6    | 6.61   | 6.91   | 6.68   | 0.153  | 0.069  | 6.91   | 6.58   |
| Total P   | 6.21   | 6.64   | 7.16   | 5.56   | 6.12   | 6.34   | 0.670  | 0.299  | 7.16   | 5.56   |

## Crosson

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD     | SE     | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|---------|--------|--------|--------|
| Alkti     | 0.53   | 0.61   | 0.92   | 0.75   | 0.79   | 0.72   | 0.172   | 0.077  | 0.92   | 0.53   |
| Alkt      | 2.18   | 2.3    | 2.61   | 2.4    | 2.46   | 2.39   | 0.182   | 0.081  | 2.61   | 2.18   |
| Al        | 68.72  | 81.58  | 86.54  | 82.15  | 87.60  | 81.32  | 8.407   | 3.760  | 87.60  | 68.72  |
| Ca        | 2.18   | 2.34   | 2.2    | 2.32   | 2.31   | 2.27   | 0.083   | 0.037  | 2.34   | 2.18   |
| Cl-       | 0.42   | 0.41   | 0.42   | 0.41   | 0.42   | 0.42   | 0.006   | 0.003  | 0.42   | 0.41   |
| Cond25    | 25.96  | 26.88  | 26.79  | 26.14  | 27.12  | 26.58  | 0.560   | 0.251  | 27.12  | 25.96  |
| DIC       | 0.82   | 0.99   | 1.17   | 0.89   | 1.07   | 0.99   | 0.156   | 0.070  | 1.17   | 0.82   |
| DOC       | 3.84   | 4.11   | 4.51   | 4.48   | 4.43   | 4.27   | 0.324   | 0.145  | 4.51   | 3.84   |
| Fe        | 247.29 | 199.65 | 444.37 | 269.31 | 304.00 | 292.92 | 103.680 | 46.367 | 444.37 | 199.65 |
| K         | 0.32   | 0.32   | 0.33   | 0.32   | 0.29   | 0.32   | 0.016   | 0.007  | 0.33   | 0.29   |
| Mg        | 0.65   | 0.65   | 0.63   | 0.64   | 0.63   | 0.64   | 0.011   | 0.005  | 0.65   | 0.63   |
| Mn        | 33.47  | 37.57  | 42.53  | 37.92  | 40.00  | 38.30  | 3.741   | 1.673  | 42.53  | 33.47  |
| Na        | 0.65   | 0.65   | 0.66   | 0.65   | 0.65   | 0.65   | 0.005   | 0.002  | 0.66   | 0.65   |
| NH4       | 16.24  | 16.7   | 22.01  | 22.66  | 25.65  | 20.65  | 4.538   | 2.029  | 25.65  | 16.24  |
| NO3       | 105.52 | 92.24  | 10.66  | 81.41  | 71.40  | 72.25  | 41.020  | 18.345 | 105.52 | 10.66  |
| TKN       | 262.29 | 273.09 | 346.55 | 269.82 | 281.61 | 286.67 | 38.218  | 17.092 | 346.55 | 262.29 |
| pH        | 5.61   | 5.57   | 5.64   | 5.61   | 5.59   | 5.60   | 0.029   | 0.013  | 5.64   | 5.57   |
| SO4       | 7.31   | 7.47   | 7.26   | 7.53   | 7.58   | 7.43   | 0.155   | 0.069  | 7.58   | 7.26   |
| Total P   | 10.22  | 9.89   | 12.66  | 7.56   | 8.41   | 9.75   | 2.187   | 0.978  | 12.66  | 7.56   |

## Delano

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD     | SE      | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|---------|---------|--------|--------|
| Alkti     | 2.51   | 2.45   | 2.56   | 2.47   | 1.79   | 2.36   | 0.359   | 0.161   | 2.56   | 1.79   |
| Alkt      | 4.14   | 4.1    | 4.17   | 4.12   | 3.15   | 3.94   | 0.491   | 0.219   | 4.17   | 3.15   |
| Al        | 45.14  | 64.4   | 87.58  | 68.31  | 213.93 | 95.87  | 75.684  | 33.847  | 213.93 | 45.14  |
| Ca        | 2.7    | 2.89   | 2.81   | 2.91   | 2.85   | 2.83   | 0.093   | 0.042   | 2.91   | 2.70   |
| Cl-       | 0.35   | 0.35   | 0.4    | 0.37   | 2.38   | 0.77   | 1.005   | 0.449   | 2.38   | 0.35   |
| Cond25    | 30.58  | 32.27  | 33.28  | 32.16  | 31.21  | 31.90  | 1.164   | 0.520   | 33.28  | 30.58  |
| DIC       | 1.45   | 1.46   | 1.66   | 1.34   | 1.50   | 1.48   | 0.130   | 0.058   | 1.66   | 1.34   |
| DOC       | 4.78   | 5.05   | 5.1    | 5.11   | 9.71   | 5.95   | 2.353   | 1.052   | 9.71   | 4.78   |
| Fe        | 200.9  | 237.78 | 304.67 | 187.72 | 727.00 | 331.61 | 252.272 | 112.820 | 727.00 | 187.72 |
| K         | 0.41   | 0.41   | 0.43   | 0.4    | 0.45   | 0.42   | 0.021   | 0.009   | 0.45   | 0.40   |
| Mg        | 0.93   | 0.94   | 0.95   | 0.94   | 0.59   | 0.87   | 0.176   | 0.079   | 0.95   | 0.59   |
| Mn        | 56.27  | 79.55  | 86.2   | 60.43  | 40.00  | 64.49  | 20.781  | 9.294   | 86.20  | 40.00  |
| Na        | 0.76   | 0.78   | 0.8    | 0.78   | 1.07   | 0.84   | 0.147   | 0.066   | 1.07   | 0.76   |
| NH4       | 14.28  | 14.03  | 14.11  | 9.59   | 78.10  | 26.02  | 32.622  | 14.589  | 78.10  | 9.59   |
| NO3       | 105.71 | 111.19 | 118.85 | 88.14  | 42.80  | 93.34  | 34.022  | 15.215  | 118.85 | 42.80  |
| TKN       | 257.84 | 275.87 | 293.12 | 268.82 | 515.28 | 322.19 | 121.531 | 54.350  | 515.28 | 257.84 |
| pH        | 6.12   | 6.06   | 6.03   | 6.14   | 5.49   | 5.97   | 0.303   | 0.135   | 6.14   | 5.49   |
| SO4       | 7.71   | 8.33   | 8.42   | 8.51   | 5.51   | 7.70   | 1.409   | 0.630   | 8.51   | 5.51   |
| Total P   | 7.12   | 7.95   | 7.98   | 7.44   | 11.87  | 8.47   | 2.164   | 0.968   | 11.87  | 7.12   |

## Hamer

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD     | SE     | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|---------|--------|--------|--------|
| Alkti     | 0.73   | 0.5    | 1.18   | 1.42   | 1.28   | 1.02   | 0.435   | 0.194  | 1.42   | 0.50   |
| Alkt      | 2.26   | 2.05   | 2.74   | 3.03   | 2.66   | 2.55   | 0.438   | 0.196  | 3.03   | 2.05   |
| Al        | 160    | 177    | 159.18 | 142.14 | 189.61 | 165.59 | 20.380  | 9.114  | 189.61 | 142.14 |
| Ca        | 2.8    | 3.52   | 3      | 2.95   | 2.81   | 3.02   | 0.329   | 0.147  | 3.52   | 2.80   |
| Cl-       | 1.70   | 1.88   | 1.89   | 2.15   | 2.37   | 2.00   | 0.294   | 0.131  | 2.37   | 1.70   |
| Cond25    | 30.90  | 38.23  | 33.30  | 30.55  | 30.98  | 32.79  | 3.610   | 1.615  | 38.23  | 30.55  |
| DIC       | 0.73   | 2.05   | 1.11   | 1.06   | 1.05   | 1.20   | 0.557   | 0.249  | 2.05   | 0.73   |
| DOC       | 10.40  | 9.63   | 8.71   | 8.18   | 9.46   | 9.28   | 0.959   | 0.429  | 10.40  | 8.18   |
| Fe        | 6.40   | 333.33 | 414.42 | 414.64 | 472.00 | 328.16 | 208.541 | 93.262 | 472.00 | 6.40   |
| K         | 0.50   | 0.55   | 0.49   | 0.41   | 0.44   | 0.48   | 0.061   | 0.027  | 0.55   | 0.41   |
| Mg        | 0.64   | 0.72   | 0.66   | 0.63   | 0.59   | 0.65   | 0.055   | 0.024  | 0.72   | 0.59   |
| Mn        | 0.60   | 45.67  | 35.8   | 38.94  | 36.00  | 31.40  | 19.761  | 8.838  | 45.67  | 0.60   |
| Na        | 0.81   | 0.99   | 1      | 1.01   | 1.07   | 0.98   | 0.110   | 0.049  | 1.07   | 0.81   |
| NH4       | 57     | 61.67  | 37.38  | 13.77  | 44.12  | 42.79  | 21.151  | 9.459  | 61.67  | 13.77  |
| NO3       | 30     | 112.67 | 31.17  | 11.2   | 42.73  | 45.55  | 43.809  | 19.592 | 112.67 | 11.20  |
| TKN       | 500.00 | 453.33 | 448.55 | 358.79 | 462.23 | 444.58 | 58.190  | 26.023 | 500.00 | 358.79 |
| pH        | 5.34   | 5.07   | 5.52   | 5.65   | 5.48   | 5.41   | 0.247   | 0.110  | 5.65   | 5.07   |
| SO4       | 6.6    | 8.4    | 6.86   | 6.22   | 5.65   | 6.75   | 1.152   | 0.515  | 8.40   | 5.65   |
| Total P   | 11.5   | 10.5   | 12.18  | 11.29  | 10.20  | 11.13  | 0.887   | 0.397  | 12.18  | 10.20  |

## Harp

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD   | SE    | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|-------|-------|--------|--------|
| Alkti     | 3.46   | 3.46   | 3.66   | 3.8    | 3.76   | 3.63   | 0.180 | 0.080 | 3.80   | 3.46   |
| Alkt      | 5.04   | 5.17   | 5.3    | 5.47   | 5.36   | 5.27   | 0.186 | 0.083 | 5.47   | 5.04   |
| Al        | 25.81  | 31.62  | 30.14  | 36.6   | 37.97  | 32.43  | 5.528 | 2.472 | 37.97  | 25.81  |
| Ca        | 2.85   | 2.92   | 2.85   | 3.01   | 2.95   | 2.92   | 0.077 | 0.034 | 3.01   | 2.85   |
| Cl-       | 1.21   | 1.41   | 1.61   | 1.88   | 2.41   | 1.70   | 0.520 | 0.232 | 2.41   | 1.21   |
| Cond25    | 33.84  | 34.97  | 36.55  | 36.84  | 38.91  | 36.22  | 2.162 | 0.967 | 38.91  | 33.84  |
| DIC       | 1.42   | 1.47   | 1.57   | 1.5    | 1.55   | 1.50   | 0.067 | 0.030 | 1.57   | 1.42   |
| DOC       | 3.52   | 3.61   | 3.53   | 3.68   | 3.83   | 3.63   | 0.144 | 0.064 | 3.83   | 3.52   |
| Fe        | 67.08  | 65.4   | 57.17  | 67.38  | 59.00  | 63.21  | 5.343 | 2.390 | 67.38  | 57.17  |
| K         | 0.57   | 0.57   | 0.57   | 0.55   | 0.53   | 0.56   | 0.021 | 0.010 | 0.57   | 0.53   |
| Mg        | 0.94   | 0.93   | 0.93   | 0.95   | 0.94   | 0.94   | 0.009 | 0.004 | 0.95   | 0.93   |
| Mn        | 14.46  | 14.73  | 19.49  | 18.66  | 17.00  | 16.87  | 2.529 | 1.131 | 19.49  | 14.46  |
| Na        | 1.23   | 1.35   | 1.44   | 1.56   | 1.79   | 1.47   | 0.240 | 0.107 | 1.79   | 1.23   |
| NH4       | 8      | 7.44   | 8.16   | 8.62   | 13.85  | 9.21   | 2.936 | 1.313 | 13.85  | 7.44   |
| NO3       | 104.06 | 116.14 | 95.21  | 98.95  | 97.61  | 102.39 | 9.322 | 4.169 | 116.14 | 95.21  |
| TKN       | 214.03 | 218.48 | 226.55 | 218.46 | 216.55 | 218.81 | 5.248 | 2.347 | 226.55 | 214.03 |
| pH        | 6.39   | 6.34   | 6.33   | 6.41   | 6.35   | 6.36   | 0.038 | 0.017 | 6.41   | 6.33   |
| SO4       | 7.48   | 7.45   | 7.45   | 7.51   | 7.37   | 7.45   | 0.059 | 0.026 | 7.51   | 7.37   |
| Total P   | 7.12   | 7.78   | 7.02   | 6.02   | 6.34   | 6.86   | 0.773 | 0.346 | 7.78   | 6.02   |

## Heney

| Parameter | 1988   | 1989   | 1990  | 1991  | 1992   | MEAN   | STD    | SE     | MAX    | MIN    |
|-----------|--------|--------|-------|-------|--------|--------|--------|--------|--------|--------|
| Alkti     | 0.73   | 0.62   | 0.28  | 0.49  | 0.65   | 0.55   | 0.197  | 0.088  | 0.73   | 0.28   |
| Alkt      | 2.34   | 2.3    | 2.05  | 2.22  | 2.35   | 2.25   | 0.138  | 0.062  | 2.35   | 2.05   |
| Al        | 22.36  | 26.76  | 37.85 | 56.8  | 48.86  | 38.53  | 16.211 | 7.250  | 56.80  | 22.36  |
| Ca        | 1.95   | 2      | 1.84  | 1.87  | 1.74   | 1.88   | 0.113  | 0.051  | 2.00   | 1.74   |
| Cl-       | 0.82   | 0.76   | 0.74  | 0.79  | 0.84   | 0.79   | 0.046  | 0.021  | 0.84   | 0.74   |
| Cond25    | 24.97  | 24.87  | 24.98 | 23.68 | 24.16  | 24.53  | 0.655  | 0.293  | 24.98  | 23.68  |
| DIC       | 0.45   | 0.35   | 0.37  | 0.45  | 0.51   | 0.43   | 0.072  | 0.032  | 0.51   | 0.35   |
| DOC       | 2.75   | 2.75   | 2.97  | 3.43  | 3.26   | 3.03   | 0.341  | 0.152  | 3.43   | 2.75   |
| Fe        | 85.93  | 63.81  | 78.77 | 145.4 | 82.00  | 91.18  | 35.155 | 15.722 | 145.40 | 63.81  |
| K         | 0.41   | 0.37   | 0.38  | 0.37  | 0.37   | 0.38   | 0.020  | 0.009  | 0.41   | 0.37   |
| Mg        | 0.58   | 0.55   | 0.55  | 0.52  | 0.49   | 0.54   | 0.037  | 0.017  | 0.58   | 0.49   |
| Mn        | 24.07  | 26.45  | 29    | 46    | 0.04   | 25.11  | 18.398 | 8.228  | 46.00  | 0.04   |
| Na        | 0.86   | 0.85   | 0.84  | 0.81  | 0.83   | 0.84   | 0.021  | 0.010  | 0.86   | 0.81   |
| NH4       | 14.4   | 10.98  | 8.39  | 21    | 22.29  | 15.41  | 6.811  | 3.046  | 22.29  | 8.39   |
| NO3       | 32.87  | 24.42  | 17.15 | 34    | 19.71  | 25.63  | 8.494  | 3.798  | 34.00  | 17.15  |
| TKN       | 228.67 | 225.35 | 220   | 268   | 230.00 | 234.40 | 21.436 | 9.586  | 268.00 | 220.00 |
| pH        | 5.96   | 5.91   | 5.72  | 5.73  | 5.85   | 5.83   | 0.119  | 0.053  | 5.96   | 5.72   |
| SO4       | 6.8    | 6.85   | 6.9   | 6.66  | 6.25   | 6.69   | 0.294  | 0.131  | 6.90   | 6.25   |
| Total P   | 6.6    | 6.49   | 5.86  | 6.03  | 5.40   | 6.08   | 0.545  | 0.244  | 6.60   | 5.40   |

## Pearceley

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD    | SE     | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Alkti     | -0.12  | -0.09  | -0.3   | -0.13  | -0.37  | -0.20  | 0.138  | 0.062  | -0.09  | -0.37  |
| Alkt      | 1.50   | 1.70   | 1.61   | 1.64   | 1.35   | 1.56   | 0.154  | 0.069  | 1.70   | 1.35   |
| Al        | 44.33  | 53.33  | 62.91  | 62.06  | 73.33  | 59.19  | 12.212 | 5.462  | 73.33  | 44.33  |
| Ca        | 1.58   | 1.65   | 1.58   | 1.65   | 1.56   | 1.60   | 0.047  | 0.021  | 1.65   | 1.56   |
| Cl-       | 0.3    | 0.31   | 0.32   | 0.31   | 0.31   | 0.31   | 0.008  | 0.004  | 0.32   | 0.30   |
| Cond25    | 19.13  | 19.73  | 20.38  | 19.66  | 19.27  | 19.63  | 0.546  | 0.244  | 20.38  | 19.13  |
| DIC       | 0.31   | 0.35   | 0.37   | 0.3    | 0.33   | 0.33   | 0.032  | 0.014  | 0.37   | 0.30   |
| DOC       | 2.4    | 2.15   | 2.14   | 1.89   | 1.60   | 2.04   | 0.339  | 0.152  | 2.40   | 1.60   |
| Fe        | 67.11  | 55.41  | 63.64  | 65.74  | 73.00  | 64.98  | 7.133  | 3.190  | 73.00  | 55.41  |
| K         | 0.33   | 0.33   | 0.32   | 0.3    | 0.28   | 0.31   | 0.024  | 0.011  | 0.33   | 0.28   |
| Mg        | 0.29   | 0.29   | 0.29   | 0.28   | 0.25   | 0.28   | 0.018  | 0.008  | 0.29   | 0.25   |
| Mn        | 63.54  | 65.64  | 59.99  | 68.95  | 75.00  | 66.62  | 6.375  | 2.851  | 75.00  | 59.99  |
| Na        | 0.47   | 0.48   | 0.49   | 0.46   | 0.43   | 0.47   | 0.024  | 0.011  | 0.49   | 0.43   |
| NH4       | 30.19  | 18.67  | 17.76  | 13.23  | 22.00  | 20.37  | 7.066  | 3.160  | 30.19  | 13.23  |
| NO3       | 42.77  | 64.07  | 49.45  | 32.64  | 34.00  | 44.59  | 14.376 | 6.429  | 64.07  | 32.64  |
| TKN       | 206.74 | 188.21 | 183.54 | 152.97 | 163.33 | 178.96 | 23.704 | 10.601 | 206.74 | 152.97 |
| pH        | 5.37   | 5.46   | 5.35   | 5.31   | 5.14   | 5.33   | 0.130  | 0.058  | 5.46   | 5.14   |
| SO4       | 5.53   | 5.65   | 5.82   | 5.97   | 6.07   | 5.81   | 0.247  | 0.111  | 6.07   | 5.53   |
| Total P   | 4.49   | 4      | 5.1    | 4.53   | 4.53   | 4.53   | 0.436  | 0.195  | 5.10   | 4.00   |

## Pincher

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD    | SE     | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Alkti     | -0.07  | 0.11   | -0.05  | 0.45   | 0.37   | 0.16   | 0.268  | 0.120  | 0.45   | -0.07  |
| Alkt      | 1.59   | 1.82   | 1.82   | 2.19   | 2.12   | 1.91   | 0.274  | 0.123  | 2.19   | 1.59   |
| Al        | 62.23  | 84.82  | 82.77  | 75.74  | 84.50  | 78.01  | 10.684 | 4.778  | 84.82  | 62.23  |
| Ca        | 1.63   | 1.6    | 1.46   | 1.58   | 1.41   | 1.54   | 0.107  | 0.048  | 1.63   | 1.41   |
| Cl-       | 0.3    | 0.31   | 0.32   | 0.3    | 0.27   | 0.30   | 0.021  | 0.010  | 0.32   | 0.27   |
| Cond25    | 21.73  | 21.89  | 21.97  | 20.04  | 19.89  | 21.10  | 1.169  | 0.523  | 21.97  | 19.89  |
| DIC       | 0.45   | 0.6    | 0.74   | 0.79   | 0.84   | 0.68   | 0.176  | 0.079  | 0.84   | 0.45   |
| DOC       | 2.34   | 2.6    | 2.49   | 2.65   | 2.96   | 2.61   | 0.257  | 0.115  | 2.96   | 2.34   |
| Fe        | 70.11  | 91.27  | 122.7  | 146.47 | 130.00 | 112.11 | 34.510 | 15.434 | 146.47 | 70.11  |
| K         | 0.35   | 0.39   | 0.45   | 0.43   | 0.39   | 0.40   | 0.043  | 0.019  | 0.45   | 0.35   |
| Mg        | 0.46   | 0.45   | 0.44   | 0.43   | 0.40   | 0.44   | 0.025  | 0.011  | 0.46   | 0.40   |
| Mn        | 47.2   | 64.21  | 58.73  | 61.49  | 67.00  | 59.73  | 8.552  | 3.824  | 67.00  | 47.20  |
| Na        | 0.56   | 0.57   | 0.57   | 0.53   | 0.53   | 0.55   | 0.024  | 0.011  | 0.57   | 0.53   |
| NH4       | 27.6   | 40.09  | 53.23  | 46.15  | 46.46  | 42.71  | 10.778 | 4.820  | 53.23  | 27.60  |
| NO3       | 43.48  | 109.82 | 144    | 52.65  | 32.95  | 76.58  | 53.684 | 24.008 | 144.00 | 32.95  |
| TKN       | 192.29 | 234.28 | 267.94 | 246.73 | 269.29 | 242.11 | 35.225 | 15.753 | 269.29 | 192.29 |
| pH        | 5.37   | 5.37   | 5.4    | 5.54   | 5.47   | 5.43   | 0.083  | 0.037  | 5.54   | 5.37   |
| SO4       | 6.62   | 6.15   | 5.99   | 5.98   | 5.79   | 6.11   | 0.351  | 0.157  | 6.62   | 5.79   |
| Total P   | 7.48   | 5.4    | 5.11   | 5.92   | 5.29   | 5.84   | 1.080  | 0.483  | 7.48   | 5.11   |

## Plastic

| Parameter | 1988  | 1989   | 1990   | 1991   | 1992   | MEAN   | STD    | SE    | MAX    | MIN    |
|-----------|-------|--------|--------|--------|--------|--------|--------|-------|--------|--------|
| Alkti     | 0.42  | 0.35   | 0.34   | 0.48   | 0.42   | 0.40   | 0.064  | 0.029 | 0.48   | 0.34   |
| Alkt      | 2.09  | 2.15   | 2.03   | 2.22   | 2.16   | 2.13   | 0.080  | 0.036 | 2.22   | 2.03   |
| Al        | 21.57 | 26.09  | 27.74  | 38.6   | 39.84  | 30.77  | 9.001  | 4.026 | 39.84  | 21.57  |
| Ca        | 1.95  | 2.01   | 1.87   | 1.97   | 1.87   | 1.93   | 0.069  | 0.031 | 2.01   | 1.87   |
| Cl-       | 0.39  | 0.4    | 0.4    | 0.41   | 0.43   | 0.41   | 0.015  | 0.007 | 0.43   | 0.39   |
| Cond25    | 22.09 | 22.31  | 22.65  | 21.77  | 22.46  | 22.26  | 0.380  | 0.170 | 22.65  | 21.77  |
| DIC       | 0.46  | 0.51   | 0.56   | 0.53   | 0.60   | 0.53   | 0.060  | 0.027 | 0.60   | 0.46   |
| DOC       | 1.98  | 2.04   | 2.06   | 2.18   | 2.11   | 2.07   | 0.085  | 0.038 | 2.18   | 1.98   |
| Fe        | 92.25 | 68.91  | 62.15  | 87.57  | 78.00  | 77.78  | 14.012 | 6.266 | 92.25  | 62.15  |
| K         | 0.21  | 0.21   | 0.21   | 0.21   | 0.21   | 0.21   | 0.002  | 0.001 | 0.21   | 0.21   |
| Mg        | 0.49  | 0.47   | 0.47   | 0.48   | 0.46   | 0.47   | 0.013  | 0.006 | 0.49   | 0.46   |
| Mn        | 40.25 | 44.51  | 43.19  | 52.28  | 50.00  | 46.05  | 5.551  | 2.483 | 52.28  | 40.25  |
| Na        | 0.5   | 0.51   | 0.52   | 0.53   | 0.51   | 0.51   | 0.013  | 0.006 | 0.53   | 0.50   |
| NH4       | 24.8  | 14.75  | 13.69  | 15.63  | 25.10  | 18.79  | 6.330  | 2.831 | 25.10  | 13.69  |
| NO3       | 23.68 | 20.45  | 17.04  | 8.91   | 27.96  | 19.61  | 8.065  | 3.607 | 27.96  | 8.91   |
| TKN       | 186   | 180.96 | 168.87 | 180.64 | 181.77 | 179.65 | 7.153  | 3.199 | 186.00 | 168.87 |
| pH        | 5.82  | 5.77   | 5.68   | 5.75   | 5.71   | 5.75   | 0.061  | 0.027 | 5.82   | 5.68   |
| SO4       | 6.67  | 6.54   | 6.63   | 6.57   | 6.59   | 6.60   | 0.057  | 0.025 | 6.67   | 6.54   |
| Total P   | 5.06  | 5.95   | 5.09   | 4.83   | 4.07   | 5.00   | 0.752  | 0.336 | 5.95   | 4.07   |

## Skidway

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD     | SE     | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|---------|--------|--------|--------|
| Alkti     | -0.11  | 0.58   | 0.66   | 0.29   | 0.15   | 0.31   | 0.353   | 0.158  | 0.66   | -0.11  |
| Alkt      | 1.58   | 2.24   | 2.4    | 2.01   | 1.87   | 2.02   | 0.358   | 0.160  | 2.40   | 1.58   |
| Al        | 89.54  | 62.18  | 81.41  | 70.81  | 110.00 | 82.79  | 20.586  | 9.206  | 110.00 | 62.18  |
| Ca        | 1.31   | 1.33   | 1.3    | 1.32   | 1.19   | 1.29   | 0.064   | 0.029  | 1.33   | 1.19   |
| Cl-       | 0.41   | 0.49   | 0.51   | 0.41   | 0.45   | 0.45   | 0.051   | 0.023  | 0.51   | 0.41   |
| Cond25    | 19.64  | 19.28  | 19.66  | 18.32  | 18.05  | 18.99  | 0.846   | 0.378  | 19.66  | 18.05  |
| DIC       | 0.48   | 0.97   | 0.94   | 0.66   | 0.61   | 0.73   | 0.240   | 0.107  | 0.97   | 0.48   |
| DOC       | 3.13   | 3.79   | 3.8    | 3.52   | 3.60   | 3.57   | 0.305   | 0.137  | 3.80   | 3.13   |
| Fe        | 170.35 | 506.06 | 641.14 | 405.08 | 236.00 | 391.73 | 215.578 | 96.409 | 641.14 | 170.35 |
| K         | 0.28   | 0.42   | 0.38   | 0.33   | 0.31   | 0.34   | 0.063   | 0.028  | 0.42   | 0.28   |
| Mg        | 0.42   | 0.41   | 0.41   | 0.41   | 0.39   | 0.41   | 0.012   | 0.005  | 0.42   | 0.39   |
| Mn        | 64.75  | 79.15  | 79.03  | 72.13  | 78.00  | 74.61  | 6.960   | 3.113  | 79.15  | 64.75  |
| Na        | 0.61   | 0.62   | 0.61   | 0.56   | 0.57   | 0.59   | 0.031   | 0.014  | 0.62   | 0.56   |
| NH4       | 20.83  | 51.75  | 59.33  | 22.42  | 49.00  | 40.67  | 19.898  | 8.899  | 59.33  | 20.83  |
| NO3       | 18.57  | 26.04  | 24.18  | 14.56  | 28.50  | 22.37  | 6.368   | 2.848  | 28.50  | 14.56  |
| TKN       | 257.99 | 335.47 | 374.87 | 298.17 | 325.00 | 318.30 | 48.677  | 21.769 | 374.87 | 257.99 |
| pH        | 5.28   | 5.56   | 5.52   | 5.44   | 5.38   | 5.44   | 0.126   | 0.056  | 5.56   | 5.28   |
| SO4       | 5.46   | 4.83   | 4.75   | 5.14   | 4.78   | 4.99   | 0.341   | 0.153  | 5.46   | 4.75   |
| Total P   | 6.72   | 7.94   | 8.83   | 9.79   | 9.15   | 8.49   | 1.332   | 0.596  | 9.79   | 6.72   |

## Westward

| Parameter | 1988   | 1989   | 1990   | 1991   | 1992   | MEAN   | STD    | SE     | MAX    | MIN    |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Alkti     | 2.33   | 2.16   | 2.4    | 2.76   | 2.73   | 2.48   | 0.292  | 0.131  | 2.76   | 2.16   |
| Alkt      | 4.02   | 3.95   | 4.03   | 4.5    | 4.46   | 4.19   | 0.296  | 0.132  | 4.50   | 3.95   |
| Al        | 5.43   | 6.26   | 8.28   | 5.97   | 16.54  | 8.50   | 5.168  | 2.311  | 16.54  | 5.43   |
| Ca        | 2.17   | 2.28   | 2.05   | 2.2    | 2.11   | 2.16   | 0.098  | 0.044  | 2.28   | 2.05   |
| Cl-       | 0.3    | 0.28   | 0.3    | 0.3    | 0.29   | 0.29   | 0.010  | 0.004  | 0.30   | 0.28   |
| Cond25    | 24.34  | 24.32  | 24.16  | 24.01  | 24.12  | 24.19  | 0.156  | 0.070  | 24.34  | 24.01  |
| DIC       | 1.25   | 1.18   | 1.23   | 1.2    | 1.42   | 1.26   | 0.107  | 0.048  | 1.42   | 1.18   |
| DOC       | 1.41   | 1.46   | 1.43   | 1.57   | 1.54   | 1.48   | 0.077  | 0.034  | 1.57   | 1.41   |
| Fe        | 63.24  | 74.09  | 85.29  | 142.49 | 122.00 | 97.42  | 37.480 | 16.762 | 142.49 | 63.24  |
| K         | 0.36   | 0.36   | 0.36   | 0.36   | 0.36   | 0.36   | 0.001  | 0.000  | 0.36   | 0.36   |
| Mg        | 0.6    | 0.6    | 0.57   | 0.59   | 0.57   | 0.59   | 0.017  | 0.007  | 0.60   | 0.57   |
| Mn        | 83.74  | 78.69  | 88.17  | 111.67 | 88.00  | 90.05  | 14.187 | 6.344  | 111.67 | 78.69  |
| Na        | 0.54   | 0.53   | 0.53   | 0.52   | 0.52   | 0.53   | 0.008  | 0.004  | 0.54   | 0.52   |
| NH4       | 33.12  | 15.86  | 18.64  | 21.71  | 31.79  | 24.22  | 8.729  | 3.904  | 33.12  | 15.86  |
| NO3       | 82.79  | 133.66 | 129.09 | 90.06  | 59.54  | 99.03  | 35.386 | 15.825 | 133.66 | 59.54  |
| TKN       | 165.98 | 162.68 | 152.71 | 185.54 | 165.48 | 166.48 | 13.330 | 5.961  | 185.54 | 152.71 |
| pH        | 6.35   | 6.27   | 6.31   | 6.45   | 6.32   | 6.34   | 0.076  | 0.034  | 6.45   | 6.27   |
| SO4       | 5.93   | 6.1    | 5.86   | 5.84   | 6.14   | 5.97   | 0.154  | 0.069  | 6.14   | 5.84   |
| Total P   | 4.14   | 4.6    | 3.27   | 3.6    | 3.67   | 3.86   | 0.580  | 0.259  | 4.60   | 3.27   |

## Young

| Parameter | 1988   | 1989   | 1990  | 1991   | 1992   | MEAN   | STD    | SE     | MAX    | MIN    |
|-----------|--------|--------|-------|--------|--------|--------|--------|--------|--------|--------|
| Alkti     | 4.88   | 6.67   | 6.69  | 6.8    | 5.10   | 6.03   | 1.065  | 0.476  | 6.80   | 4.88   |
| Alkt      | 6.55   | 4.99   | 5     | 5.14   | 6.59   | 5.65   | 0.938  | 0.420  | 6.59   | 4.99   |
| Al        | 7.00   | 9.67   | 16.42 | 15.19  | 19.76  | 13.61  | 5.792  | 2.590  | 19.76  | 7.00   |
| Ca        | 2.85   | 2.93   | 2.75  | 2.89   | 2.79   | 2.84   | 0.081  | 0.036  | 2.93   | 2.75   |
| Cl-       | 0.30   | 0.38   | 0.38  | 0.39   | 0.40   | 0.37   | 0.044  | 0.020  | 0.40   | 0.30   |
| Cond25    | 30.10  | 31.77  | 30.9  | 30.52  | 30.34  | 30.73  | 0.730  | 0.326  | 31.77  | 30.10  |
| DIC       | 1.29   | 1.78   | 1.71  | 1.5    | 1.61   | 1.58   | 0.215  | 0.096  | 1.78   | 1.29   |
| DOC       | 3.50   | 2.97   | 3.04  | 3.23   | 3.07   | 3.16   | 0.236  | 0.106  | 3.50   | 2.97   |
| Fe        | 33.00  | 39.33  | 33.23 | 31.84  | 39.00  | 35.28  | 4.011  | 1.794  | 39.33  | 31.84  |
| K         | 0.59   | 0.57   | 0.56  | 0.55   | 0.53   | 0.56   | 0.026  | 0.012  | 0.59   | 0.53   |
| Mg        | 0.76   | 0.78   | 0.75  | 0.77   | 0.73   | 0.76   | 0.021  | 0.009  | 0.78   | 0.73   |
| Mn        | 18.00  | 15.67  | 48.29 | 33.52  | 35.00  | 30.10  | 15.013 | 6.714  | 48.29  | 15.67  |
| Na        | 0.95   | 0.94   | 0.94  | 0.92   | 0.92   | 0.93   | 0.015  | 0.007  | 0.95   | 0.92   |
| NH4       | 9.00   | 11.00  | 14.74 | 11.32  | 13.35  | 11.88  | 2.482  | 1.110  | 14.74  | 9.00   |
| NO3       | 5.00   | 145.00 | 64.82 | 62.57  | 68.17  | 69.11  | 55.710 | 24.914 | 145.00 | 5.00   |
| TKN       | 210.00 | 223.33 | 245   | 232.52 | 233.73 | 228.92 | 14.618 | 6.538  | 245.00 | 210.00 |
| pH        | 6.88   | 6.37   | 6.61  | 6.83   | 6.63   | 6.66   | 0.227  | 0.101  | 6.88   | 6.37   |
| SO4       | 6.80   | 6.53   | 6.20  | 6.28   | 6.52   | 6.47   | 0.264  | 0.118  | 6.80   | 6.20   |
| Total P   | 8.3    | 8.58   | 8.44  | 7.49   | 7.65   | 8.09   | 0.548  | 0.245  | 8.58   | 7.49   |

#### Appendix 4

Percentages of male and female crayfish in the biomonitoring lakes 1988-1992

Appendix 4: Percentages of Male and Female Crayfish in the Biomonitoring Lakes

1988 - 1992

| <u>Lake</u>       | <u>Sample Date</u> | <u>Species</u> | <u>Female</u> | <u>Male</u> | <u>Total</u> | <u>%F</u> | <u>%M</u> |
|-------------------|--------------------|----------------|---------------|-------------|--------------|-----------|-----------|
| <u>Blue Chalk</u> | July 22, 1988      | Cb             | 63            | 111         | 174          | 0.36      | 0.64      |
|                   |                    | Op             | 359           | 387         | 746          | 0.48      | 0.52      |
|                   |                    | Ov             | 85            | 113         | 198          | 0.43      | 0.57      |
|                   | July 13, 1989      | Cb             | 26            | 19          | 45           | 0.58      | 0.42      |
|                   |                    | Op             | 264           | 282         | 546          | 0.48      | 0.52      |
|                   |                    | Ov             | 39            | 65          | 104          | 0.38      | 0.63      |
|                   | July 24, 1990      | Cb             | 3             | 3           | 6            | 0.50      | 0.50      |
|                   |                    | Op             | 14            | 22          | 36           | 0.39      | 0.61      |
|                   |                    | Ov             | 5             | 28          | 33           | 0.15      | 0.85      |
|                   | July 5, 1991       | Cb             | 20            | 14          | 34           | 0.59      | 0.41      |
|                   |                    | Op             | 88            | 114         | 202          | 0.44      | 0.56      |
|                   |                    | Ov             | 28            | 30          | 58           | 0.48      | 0.52      |
|                   | June 30, 1992      | Cb             | 13            | 12          | 25           | 0.52      | 0.48      |
|                   |                    | Op             | 130           | 105         | 235          | 0.55      | 0.45      |
|                   |                    | Ov             | 37            | 33          | 70           | 0.53      | 0.47      |
| <u>Clear</u>      | July 25, 1988      | Cb             | 50            | 99          | 149          | 0.34      | 0.66      |
|                   |                    | Op             | 165           | 155         | 320          | 0.52      | 0.48      |
|                   | August 2, 1989     | Cb             | 32            | 58          | 90           | 0.36      | 0.64      |
|                   |                    | Op             | 38            | 46          | 84           | 0.45      | 0.55      |
|                   | July 19, 1990      | Cb             | 5             | 37          | 42           | 0.12      | 0.88      |
|                   |                    | Op             | 14            | 20          | 34           | 0.41      | 0.59      |
|                   | July 09, 1991      | Cb             | 3             | 27          | 30           | 0.10      | 0.90      |
|                   |                    | Op             | 77            | 70          | 147          | 0.52      | 0.48      |
|                   | July 16, 1992      | Cb             | 2             | 26          | 28           | 0.07      | 0.93      |
|                   |                    | Op             | 21            | 27          | 48           | 0.44      | 0.56      |
| <u>Cradle</u>     | August 30, 1988    | Cb             | 1077          | 1137        | 2214         | 0.49      | 0.51      |
|                   | August 1, 1989     |                | 508           | 548         | 1056         | 0.48      | 0.52      |
|                   | July 5, 1990       |                | 71            | 112         | 183          | 0.39      | 0.61      |
|                   | July 19, 1991      |                | 118           | 180         | 298          | 0.40      | 0.60      |
|                   | July 7, 1992       |                | 131           | 248         | 379          | 0.35      | 0.65      |
| <u>Crosson</u>    | July 20, 1988      | Cb             | 47            | 38          | 85           | 0.55      | 0.45      |
|                   |                    | Ov             | 165           | 225         | 390          | 0.42      | 0.58      |
|                   | August 1, 1989     | Cb             | 4             | 10          | 14           | 0.29      | 0.71      |
|                   |                    | Ov             | 26            | 51          | 77           | 0.34      | 0.66      |
|                   | August 9, 1990     | Cb             | 1             | 3           | 4            | 0.25      | 0.75      |
|                   |                    | Ov             | 9             | 21          | 30           | 0.30      | 0.70      |
|                   | July 30, 1991      | Cb             | 9             | 4           | 13           | 0.69      | 0.31      |
|                   |                    | Ov             | 11            | 19          | 30           | 0.37      | 0.63      |
|                   | July 9, 1992       | Cb             | 0             | 1           | 1            | 0.00      | 1.00      |
|                   |                    | Ov             | 23            | 23          | 46           | 0.50      | 0.50      |
|                   |                    |                |               |             |              |           |           |
| <u>Delano</u>     | August 11, 1988    | Cb             | 3             | 1           | 4            | 0.75      | 0.25      |
|                   |                    | Op             | 105           | 53          | 158          | 0.66      | 0.34      |
|                   |                    | Ov             | 2             | 0           | 2            | 1.00      | 0.00      |
|                   | July 18, 1989      | Cb             | 3             | 2           | 5            | 0.60      | 0.40      |
|                   |                    | Op             | 36            | 27          | 63           | 0.57      | 0.43      |
|                   |                    | Ov             | 0             | 1           | 1            | 0.00      | 1.00      |
|                   | July 4, 1990       | Op             | 14            | 1           | 15           | 0.93      | 0.07      |
|                   |                    | Cb             |               | 3           | 3            | 0.00      | 1.00      |
|                   | July 19, 1991      | Op             | 16            | 23          | 39           | 0.41      | 0.59      |
|                   |                    | Op             | 28            | 21          | 49           | 0.57      | 0.43      |
|                   | July 7, 1992       | Op             |               |             |              |           |           |

## Appendix 4. (cont'd)

| Lake             | Sample Date     | Species | Female | Male | Total | %F   | %M   |
|------------------|-----------------|---------|--------|------|-------|------|------|
| <u>Hamer</u>     | August 4, 1988  | Ov      | 37     | 17   | 54    | 0.69 | 0.31 |
|                  | July 26, 1989   |         | 22     | 52   | 74    | 0.30 | 0.70 |
|                  | July 11, 1990   |         | 2      | 18   | 20    | 0.10 | 0.90 |
|                  | August 1, 1991  |         | 10     | 34   | 44    | 0.23 | 0.77 |
|                  | July 3, 1992    |         | 16     | 19   | 35    | 0.46 | 0.54 |
| <u>Harp</u>      | July 28, 1988   | Cb      | 8      | 13   | 21    | 0.38 | 0.62 |
|                  |                 | Op      | 7      | 2    | 9     | 0.78 | 0.22 |
|                  | July 14, 1989   | Cb      | 1      | 3    | 4     | 0.25 | 0.75 |
|                  |                 | Op      | 2      | 2    | 4     | 0.50 | 0.50 |
|                  | July 12, 1990   | Op      | 1      | 1    | 2     | 0.50 | 0.50 |
| <u>Heney</u>     | July 11, 1991   |         |        |      | 0     |      |      |
|                  | July 8, 1992    |         |        |      | 0     |      |      |
|                  | July 27, 1990   | Ov      | 15     | 10   | 25    | 0.60 | 0.40 |
|                  | July 9, 1991    |         | 6      | 9    | 15    | 0.40 | 0.60 |
|                  | July 8, 1992    |         | 13     | 12   | 25    | 0.52 | 0.48 |
| <u>Pearceley</u> | July 6, 1990    | Cb      | 4      | 20   | 24    | 0.17 | 0.83 |
|                  | July 23, 1991   |         | 5      | 4    | 9     | 0.56 | 0.44 |
|                  | July 14, 1992   |         |        |      | 0     |      |      |
| <u>Pincher</u>   | August 28, 1988 | Cb      | 313    | 180  | 493   | 0.63 | 0.37 |
|                  | July 21, 1989   |         | 43     | 62   | 105   | 0.41 | 0.59 |
|                  | July 10, 1990   |         | 1      | 6    | 7     | 0.14 | 0.86 |
|                  | July 23, 1991   |         | 15     | 7    | 22    | 0.68 | 0.32 |
|                  | July 14, 1992   |         | 6      | 3    | 9     | 0.67 | 0.33 |
| <u>Plastic</u>   | July 18, 1988   |         |        |      | 0     |      |      |
|                  | July 20, 1989   |         |        |      | 0     |      |      |
|                  | July 5, 1990    |         |        |      | 0     |      |      |
|                  | July 3, 1991    |         |        |      | 0     |      |      |
|                  | July 3, 1992    |         |        |      | 0     |      |      |
| <u>Skidway</u>   | August 3, 1988  | Ov      | 28     | 26   | 54    | 0.52 | 0.48 |
|                  | July 25, 1989   |         | 16     | 21   | 37    | 0.43 | 0.57 |
|                  | July 13, 1990   |         | 2      | 2    | 4     | 0.50 | 0.50 |
|                  | August 7, 1991  |         | 16     | 17   | 33    | 0.48 | 0.52 |
|                  | July 16, 1992   |         | 4      | 6    | 10    | 0.40 | 0.60 |
| <u>Westward</u>  | August 17, 1988 | Cb      | 448    | 485  | 933   | 0.48 | 0.52 |
|                  |                 | Op      | 111    | 102  | 213   | 0.52 | 0.48 |
|                  | July 19, 1989   | Cb      | 88     | 143  | 231   | 0.38 | 0.62 |
|                  |                 | Op      | 30     | 28   | 58    | 0.52 | 0.48 |
|                  | July 10, 1990   | Cb      | 17     | 23   | 40    | 0.42 | 0.58 |
|                  |                 | Op      | 24     | 12   | 36    | 0.67 | 0.33 |
|                  | July 17, 1991   | Cb      | 35     | 49   | 84    | 0.42 | 0.58 |
|                  |                 | Op      | 38     | 24   | 62    | 0.61 | 0.39 |
|                  | July 14, 1992   | Cb      | 36     | 48   | 84    | 0.43 | 0.57 |
|                  |                 | Op      | 52     | 26   | 78    | 0.67 | 0.33 |
| <u>Young</u>     | August 9, 1988  | Op      | 29     | 14   | 43    | 0.67 | 0.33 |
|                  | August 7, 1989  |         | 4      | 2    | 6     | 0.67 | 0.33 |
|                  | July 11, 1990   |         | 2      | 15   | 17    | 0.12 | 0.88 |
|                  | August 1, 1991  |         | 2      |      | 2     | 1.00 | 0.00 |
|                  | July 3, 1992    |         | 2      | 2    | 4     | 0.50 | 0.50 |



## Appendix 5

Carapace length ranges and means for Cambarus bartoni

Appendix 5: Carapace Length Ranges and Means for *Cambarus bartoni*

| <u>Lake</u> | <u>Year</u> | <u>Sex</u> | <u>Sample Size</u> | <u>Min.</u> | <u>Max.</u> | <u>Mean</u> |
|-------------|-------------|------------|--------------------|-------------|-------------|-------------|
| Blue Chalk  | 1988        | female     | 63                 | 9.5         | 37.0        | 28.6        |
|             |             | male FI    | 69                 | 24.0        | 38.7        | 32.7        |
|             |             | male FII   | 42                 | 18.6        | 35.0        | 27.6        |
|             | 1989        | female     | 26                 | 26.2        | 32.1        | 28.5        |
|             |             | male FI    | 4                  | 25.5        | 26.1        | 25.9        |
|             | 1990        | male FII   | 1                  | 28.3        | 28.3        | 28.3        |
|             |             | female     | 3                  | 29.3        | 29.7        | 29.5        |
|             |             | male FI    | 3                  | 27.2        | 36.1        | 30.2        |
|             | 1991        | female     | 20                 | 27.0        | 41.7        | 32.3        |
|             |             | male FII   | 14                 | 23.1        | 35.7        | 31.3        |
|             | 1992        | female     | 13                 | 25.5        | 39.0        | 31.3        |
|             |             | male FI    | 6                  | 26.1        | 35.5        | 30.3        |
|             |             | male FII   | 6                  | 22.5        | 33.6        | 28.7        |
| Clear       | 1988        | female     | 50                 | 19.4        | 37.8        | 27.5        |
|             |             | male FI    | 20                 | 22.9        | 37.4        | 30.2        |
|             |             | male FII   | 79                 | 15.4        | 39.4        | 28.9        |
|             | 1989        | female     | 32                 | 20.0        | 38.2        | 28.6        |
|             |             | male FI    | 48                 | 24.5        | 37.0        | 31.9        |
|             |             | male FII   | 10                 | 20.0        | 30.5        | 24.2        |
|             | 1990        | female     | 5                  | 21.3        | 28.3        | 26.0        |
|             |             | male FI    | 9                  | 24.3        | 37.1        | 31.1        |
|             |             | male FII   | 28                 | 19.4        | 36.1        | 29.9        |
|             | 1991        | female     | 3                  | 21.5        | 31.1        | 26.8        |
|             |             | male FI    | 21                 | 22.5        | 36.8        | 32.0        |
|             | 1992        | male FII   | 6                  | 24.2        | 31.6        | 28.9        |
|             |             | female     | 2                  | 33.0        | 33.1        | 33.1        |
|             |             | male FI    | 2                  | 33.1        | 40.4        | 36.8        |
|             |             | male FII   | 24                 | 21.4        | 35.4        | 29.8        |

| <u>Lake</u> | <u>Year</u> | <u>Sex</u> | <u>Sample Size</u> | <u>Min.</u> | <u>Max.</u> | <u>Mean</u> |
|-------------|-------------|------------|--------------------|-------------|-------------|-------------|
| Cradle      | 1988        | female     | 1077               | 14.2        | 33.2        | 22.2        |
|             |             | male FI    | 435                | 20.5        | 38.0        | 24.5        |
|             |             | male FII   | 702                | 15.2        | 194.0       | 22.7        |
|             | 1989        | female     | 508                | 13.7        | 30.3        | 22.8        |
|             |             | male FI    | 140                | 21.5        | 27.4        | 24.2        |
|             |             | male FII   | 408                | 15.8        | 30.7        | 22.7        |
|             | 1990        | female     | 71                 | 16.3        | 35.7        | 23.1        |
|             |             | male FI    | 42                 | 22.0        | 34.5        | 26.2        |
|             | 1991        | male FII   | 70                 | 15.1        | 30.3        | 23.1        |
|             |             | female     | 118                | 18.5        | 33.5        | 24.7        |
|             | 1992        | male FII   | 180                | 15.2        | 34.0        | 25.5        |
|             |             | female     | 131                | 13.0        | 29.0        | 21.8        |
|             |             | male FI    | 131                | 20.4        | 33.0        | 27.1        |
|             |             | male FII   | 117                | 12.8        | 31.4        | 22.1        |
| Crosson     | 1988        | female     | 47                 | 25.4        | 42.7        | 34.9        |
|             |             | male FI    | 23                 | 29.2        | 39.8        | 35.0        |
|             |             | male FII   | 15                 | 26.5        | 40.8        | 32.6        |
|             | 1989        | female     | 4                  | 34.1        | 37.9        | 35.6        |
|             |             | male FI    | 10                 | 29.0        | 40.0        | 35.6        |
|             | 1990        | female     | 1                  | 38.7        | 38.7        | 38.7        |
|             |             | male FI    | 3                  | 30.5        | 35.8        | 33.9        |
|             | 1991        | female     | 9                  | 33.2        | 41.5        | 38.1        |
|             |             | male FII   | 4                  | 33.5        | 39.9        | 36.1        |
|             | 1992        | male FI    | 1                  | 34.5        | 34.5        | 34.5        |
|             |             | male FII   | 3                  | 28.0        | 35.3        | 32.2        |
|             | 1989        | female     | 1                  | 29.0        | 29.0        | 29.0        |
|             |             | male FI    | 3                  | 32.7        | 34.4        | 33.3        |
|             |             | male FII   | 2                  | 35.4        | 35.8        | 35.6        |
| Delano      | 1991        | male FII   | 3                  | 28.0        | 35.0        | 32.0        |

Appendix 5. (cont'd)

| <u>Lake</u> | <u>Year</u> | <u>Sex</u> | <u>Sample Size</u> | <u>Min.</u> | <u>Max.</u> | <u>Mean</u> |
|-------------|-------------|------------|--------------------|-------------|-------------|-------------|
| Harp        | 1988        | female     | 8                  | 27.5        | 39.9        | 33.5        |
|             |             | male FI    | 12                 | 30.0        | 41.0        | 36.9        |
|             |             | male FI    | 1                  | 29.3        | 29.3        | 29.3        |
|             | 1989        | female     | 1                  | 31.3        | 31.3        | 31.3        |
|             |             | male FI    | 1                  | 34.0        | 34.0        | 34.0        |
|             |             | male FI    | 2                  | 28.6        | 34.0        | 31.3        |
| Pincher     | 1988        | female     | 313                | 19.6        | 34.7        | 27.8        |
|             |             | male FI    | 142                | 20.2        | 33.8        | 26.3        |
|             |             | male FI    | 38                 | 19.1        | 28.5        | 24.0        |
|             | 1989        | female     | 43                 | 19.2        | 33.0        | 26.9        |
|             |             | male FI    | 11                 | 21.4        | 37.0        | 29.0        |
|             |             | male FI    | 51                 | 19.4        | 33.3        | 28.5        |
|             | 1990        | female     | 1                  | 22.3        | 22.3        | 22.3        |
|             |             | male FI    | 6                  | 26.0        | 30.7        | 28.4        |
|             | 1991        | female     | 15                 | 18.0        | 32.1        | 26.9        |
|             |             | male FI    | 7                  | 19.0        | 28.8        | 25.2        |
| 1992        | female      | 6          | 24.7               | 28.3        | 26.2        |             |
|             | male FI     | 1          | 26.9               | 26.9        | 26.9        |             |
|             | male FI     | 2          | 28.2               | 30.0        | 29.1        |             |

| <u>Lake</u> | <u>Year</u> | <u>Sex</u> | <u>Sample Size</u> | <u>Min.</u> | <u>Max.</u> | <u>Mean</u> |
|-------------|-------------|------------|--------------------|-------------|-------------|-------------|
| Westward    | 1988        | female     | 448                | 13.1        | 38.5        | 24.3        |
|             |             | male FI    | 192                | 20.4        | 32.6        | 26.1        |
|             |             | male FI    | 293                | 12.0        | 32.9        | 23.4        |
|             | 1989        | female     | 88                 | 18.3        | 34.7        | 25.8        |
|             |             | male FI    | 90                 | 21.5        | 36.8        | 27.4        |
|             |             | male FI    | 53                 | 16.9        | 33.3        | 24.1        |
|             | 1990        | female     | 17                 | 16.0        | 35.9        | 24.7        |
|             |             | male FI    | 13                 | 23.4        | 34.5        | 29.4        |
|             |             | male FI    | 10                 | 17.6        | 36.2        | 24.6        |
|             | 1991        | female     | 35                 | 15.7        | 33.4        | 24.4        |
|             |             | male FI    | 49                 | 22.0        | 34.0        | 27.3        |
|             | 1992        | female     | 36                 | 14.6        | 36.7        | 25.3        |
|             | male FI     | 23         | 22.6               | 36.0        | 28.6        |             |
|             | male FI     | 25         | 17.0               | 35.2        | 23.4        |             |



## Appendix 6

Carapace length ranges and means for Orconectes propinquus

Appendix 6: Carapace Length Ranges and Means for *Orconectes propinquus*

| <u>Lake</u> | <u>Year</u> | <u>Sex</u> | <u>Sample</u> | <u>Min.</u> | <u>Max.</u> | <u>Mean</u> |
|-------------|-------------|------------|---------------|-------------|-------------|-------------|
|             |             |            | <u>Size</u>   |             |             |             |
| Blue Chalk  | 1988        | female     | 359           | 10.0        | 29.1        | 20.7        |
|             |             | male FI    | 150           | 17.5        | 29.8        | 22.9        |
|             | 1989        | female     | 237           | 10.6        | 26.0        | 19.5        |
|             |             | male FI    | 264           | 13.8        | 31.0        | 21.3        |
|             | 1990        | female     | 65            | 20.6        | 31.1        | 24.2        |
|             |             | male FI    | 217           | 13.3        | 29.1        | 21.5        |
|             | 1991        | female     | 14            | 13.9        | 33.4        | 21.6        |
|             |             | male FI    | 6             | 20.9        | 29.4        | 24.2        |
|             | 1992        | female     | 16            | 18.8        | 24.3        | 21.7        |
|             |             | male FI    | 88            | 14.9        | 29.8        | 22.3        |
|             | 1993        | female     | 114           | 14.6        | 33.3        | 21.9        |
|             |             | male FI    | 130           | 14.1        | 33.3        | 21.9        |
| Clear       | 1988        | female     | 105           | 14.8        | 34.0        | 21.7        |
|             |             | male FI    | 165           | 15.1        | 30.0        | 22.1        |
|             | 1989        | female     | 70            | 18.6        | 29.3        | 23.1        |
|             |             | male FI    | 85            | 10.5        | 29.6        | 21.3        |
|             | 1990        | female     | 38            | 13.0        | 29.0        | 20.5        |
|             |             | male FI    | 13            | 21.0        | 28.5        | 24.7        |
|             | 1991        | female     | 33            | 16.5        | 28.0        | 21.4        |
|             |             | male FI    | 14            | 15.9        | 27.5        | 22.3        |
|             | 1992        | female     | 3             | 21.1        | 26.7        | 24.0        |
|             |             | male FI    | 17            | 19.4        | 26.8        | 22.7        |
|             | 1993        | female     | 77            | 12.0        | 30.5        | 21.8        |
|             |             | male FI    | 2             | 25.1        | 28.8        | 27.0        |
| Delano      | 1988        | female     | 68            | 13.5        | 30.0        | 20.9        |
|             |             | male FI    | 21            | 19.3        | 29.0        | 23.8        |
|             | 1989        | female     | 27            | 19.6        | 28.1        | 23.4        |
|             |             | male FI    | 105           | 18.8        | 35.7        | 28.3        |
|             | 1990        | female     | 50            | 20.8        | 38.9        | 28.9        |
|             |             | male FI    | 3             | 18.8        | 23.0        | 21.3        |
|             | 1991        | female     | 36            | 22.4        | 34.4        | 28.7        |
|             |             | male FI    | 17            | 23.5        | 34.6        | 30.2        |
|             | 1992        | female     | 10            | 19.5        | 26.6        | 22.8        |
|             |             | male FI    | 14            | 17.0        | 33.9        | 26.6        |
|             | 1993        | female     | 1             | 23.5        | 23.5        | 23.5        |
|             |             | male FI    |               |             |             |             |

| <u>Lake</u> | <u>Year</u> | <u>Sex</u> | <u>Sample</u> | <u>Min.</u> | <u>Max.</u> | <u>Mean</u> |
|-------------|-------------|------------|---------------|-------------|-------------|-------------|
|             |             |            | <u>Size</u>   |             |             |             |
| Delano      | 1991        | female     | 16            | 22.0        | 34.2        | 29.1        |
|             |             | male FI    | 23            | 20.0        | 35.7        | 27.4        |
|             | 1992        | female     | 28            | 18.0        | 30.7        | 24.5        |
|             |             | male FI    | 15            | 19.0        | 32.3        | 25.5        |
| Harp        | 1988        | female     | 7             | 25.1        | 30.5        | 27.3        |
|             |             | male FI    | 2             | 25.2        | 26.0        | 25.6        |
|             | 1989        | female     | 2             | 25.5        | 32.3        | 28.9        |
|             |             | male FI    | 2             | 19.7        | 26.4        | 23.1        |
| Westward    | 1990        | female     | 1             | 23.2        | 23.2        | 23.2        |
|             |             | male FI    | 1             | 22.0        | 22.0        | 22.0        |
|             | 1988        | female     | 111           | 14.1        | 32.4        | 22.3        |
|             |             | male FI    | 83            | 19.0        | 30.9        | 22.9        |
| Young       | 1989        | female     | 19            | 18.2        | 23.0        | 20.4        |
|             |             | male FI    | 30            | 18.7        | 29.1        | 23.8        |
|             | 1990        | female     | 11            | 17.3        | 25.2        | 21.0        |
|             |             | male FI    | 24            | 14.4        | 27.6        | 22.8        |
| Young       | 1991        | female     | 2             | 24.3        | 24.8        | 24.6        |
|             |             | male FI    | 10            | 15.5        | 30.4        | 22.1        |
|             | 1992        | female     | 38            | 18.0        | 31.5        | 24.7        |
|             |             | male FI    | 24            | 16.9        | 31.5        | 25.0        |
|             | 1988        | female     | 52            | 19.4        | 28.7        | 23.6        |
|             |             | male FI    | 14            | 23.5        | 30.9        | 27.2        |
|             | 1989        | female     | 29            | 15.3        | 31.0        | 19.8        |
|             |             | male FI    | 11            | 17.1        | 23.0        | 20.7        |
|             | 1990        | female     | 3             | 14.7        | 21.0        | 17.6        |
|             |             | male FI    | 4             | 14.5        | 22.5        | 18.3        |
|             | 1991        | female     | 2             | 18.3        | 19.6        | 19.0        |
|             |             | male FI    | 2             | 17.0        | 23.0        | 20.0        |
| Westward    | 1991        | female     | 15            | 12.0        | 30.0        | 19.9        |
|             |             | male FI    | 2             | 18.1        | 19.8        | 19.0        |
|             | 1992        | female     | 2             | 19.1        | 20.7        | 19.9        |
|             |             | male FI    | 1             | 28.0        | 28.0        | 28.0        |
| Westward    | 1993        | female     | 1             | 17.5        | 17.5        | 17.5        |
|             |             | male FI    |               |             |             |             |

## Appendix 7

Carapace length ranges and means for Orconectes virilis

Appendix 7: Carapace Length Ranges and Means for *Orconectes virilis*

| Lake       | Year | Sex      | Sample Size | Min. | Max. | Mean |
|------------|------|----------|-------------|------|------|------|
| Blue Chalk | 1988 | female   | 85          | 17.9 | 37.1 | 27.1 |
|            |      | male FI  | 17          | 21.0 | 38.8 | 31.7 |
|            |      | male FII | 96          | 16.3 | 38.0 | 28.5 |
|            | 1989 | female   | 39          | 19.3 | 32.5 | 27.0 |
|            |      | male FII | 65          | 24.0 | 36.0 | 29.4 |
|            | 1990 | female   | 4           | 16.2 | 32.5 | 22.3 |
|            |      | male FI  | 1           | 35.6 | 35.6 | 35.6 |
|            | 1991 | male FII | 27          | 18.8 | 34.3 | 28.1 |
|            |      | female   | 28          | 15.1 | 31.7 | 25.9 |
|            |      | male FII | 30          | 20.9 | 36.5 | 29.7 |
|            | 1992 | female   | 37          | 20.0 | 33.3 | 27.5 |
|            |      | male FI  | 3           | 34.3 | 36.6 | 35.2 |
|            |      | male FII | 30          | 19.5 | 35.9 | 27.5 |
| Crosson    | 1988 | female   | 165         | 19.8 | 39.7 | 28.7 |
|            |      | male FI  | 17          | 22.3 | 36.0 | 31.1 |
|            |      | male FII | 208         | 18.8 | 37.2 | 30.2 |
|            | 1989 | female   | 26          | 21.9 | 36.0 | 27.7 |
|            |      | male FI  | 29          | 24.2 | 37.1 | 30.4 |
|            |      | male FII | 22          | 16.1 | 35.2 | 25.0 |
|            | 1990 | female   | 9           | 20.9 | 35.5 | 27.5 |
|            |      | male FI  | 1           | 32.7 | 32.7 | 32.7 |
|            |      | male FII | 20          | 19.4 | 32.9 | 27.0 |
|            | 1991 | female   | 11          | 27   | 37.0 | 30.6 |
|            |      | male FI  | 6           | 28.5 | 38.5 | 32.7 |
|            |      | male FII | 13          | 26   | 36.1 | 30.8 |
|            | 1992 | female   | 23          | 22.9 | 35.8 | 28.7 |
|            |      | male FI  | 1           | 33.7 | 33.7 | 33.7 |
|            |      | male FII | 22          | 25.3 | 37.7 | 31.9 |
| Delano     | 1988 | female   | 2           | 31.1 | 36.7 | 33.9 |
|            | 1989 | male FII | 1           | 33.9 | 33.9 | 33.9 |

| Lake    | Year | Sex      | Sample Size | Min. | Max. | Mean |
|---------|------|----------|-------------|------|------|------|
| Hamer   | 1988 | female   | 14          | 25.8 | 36.6 | 32.1 |
|         |      | male FI  | 37          | 30.2 | 48.2 | 40.3 |
|         |      | male FII | 17          | 22.3 | 39.0 | 32.0 |
|         | 1989 | female   | 22          | 29.1 | 44.6 | 36.0 |
|         |      | male FI  | 27          | 38.4 | 46.7 | 42.5 |
|         |      | male FII | 25          | 27.3 | 48.8 | 36.4 |
|         | 1990 | female   | 3           | 27   | 40.0 | 35.7 |
|         |      | male FII | 17          | 32   | 49.0 | 42.3 |
|         | 1991 | female   | 10          | 27.8 | 41.2 | 33.8 |
|         |      | male FI  | 17          | 39.1 | 49.3 | 43.3 |
|         |      | male FII | 17          | 26   | 48.1 | 34.0 |
|         | 1992 | female   | 16          | 30.6 | 42.7 | 34.9 |
|         |      | male FII | 19          | 22.8 | 45.3 | 38.5 |
| Heney   | 1990 | female   | 15          | 24.9 | 36.6 | 31.1 |
|         |      | male FI  | 2           | 35.2 | 36.7 | 36.0 |
|         |      | male FII | 8           | 20.5 | 37.3 | 29.0 |
|         | 1991 | female   | 6           | 25   | 34.2 | 29.5 |
|         |      | male FII | 9           | 27.2 | 36.4 | 31.1 |
|         | 1992 | female   | 13          | 22.7 | 38.0 | 29.9 |
|         |      | male FI  | 12          | 25.4 | 36.0 | 30.3 |
|         |      | female   | 28          | 24.0 | 46.7 | 36.5 |
| Skidway | 1988 | female   | 13          | 30.3 | 45.9 | 41.0 |
|         |      | male FI  | 13          | 28.8 | 41.9 | 35.0 |
|         |      | male FII | 16          | 27.5 | 44.6 | 36.7 |
|         | 1989 | female   | 2           | 42.9 | 45.2 | 44.1 |
|         |      | male FI  | 19          | 15.7 | 43.2 | 35.4 |
|         |      | male FII | 2           | 23.2 | 24.3 | 23.8 |
|         | 1990 | female   | 1           | 40.9 | 40.9 | 40.9 |
|         |      | male FI  | 1           | 29.2 | 29.2 | 29.2 |
|         |      | male FII | 16          | 30.0 | 38.0 | 34.4 |
|         | 1991 | female   | 5           | 35.9 | 42.1 | 39.5 |
|         |      | male FI  | 12          | 26.9 | 41.0 | 33.1 |
|         |      | male FII | 4           | 19.8 | 35.0 | 29.6 |
|         | 1992 | female   | 6           | 25.5 | 43.8 | 36.6 |

## Appendix 8

### Crayfish sampling protocol

### Equipment List

- boat/canoe and motor; gas tank, paddles, life jackets, bailing bucket
- note: canoe used for fly-in lakes
- road map
- 1:50,000 topographic area map
- lake map
- field book
- pencils
- thermometer or thermistor
- 54 crayfish traps (modified minnow traps)
- 1 full set of floats and ropes per lake  
(i.e., 18 traps per site; 3 sets of 1 - 6 metres; a total of 9 sets per lake for 54 traps)
- crayfish bait (film vials filled with fish-flavoured canned cat food) 1 vial per trap; 54 per lake
- vernier calipers for measuring the crayfish length

All equipment should be ready one week prior to the first sampling date. A truck should be reserved for crayfish sampling use only (see Jim Jones, to ensure that a truck is always available).

Sampling should begin during the last week of June, or the first week of July. The first lakes to be sampled are the 16 biomonitoring lakes listed below which are sampled every year:

|            |                           |           |           |
|------------|---------------------------|-----------|-----------|
| Blue Chalk | Delano*                   | Mouse     | Ranger    |
| Clear      | Hamer                     | Pearceley | Skidway*  |
| Cradle*    | Harp                      | Plastic   | Westward* |
| Crosson    | Heney (no motors allowed) | Pincher*  | Young     |

\* these lakes are fly-in lakes for which flights are pre-arranged through the Ontario Ministry of Natural Resources at Smoke Lake.

Maps for the biomonitoring lakes have the three crayfish trapping sites identified. These sites must be used, as the same ones are sampled every year.

An additional set of survey lakes (usually around 20) for a designated watershed are also sampled. As with the biomonitoring lakes, three sites are trapped per lake. These sites should represent major habitat types, characteristic of lakes in the region (ideally detritus, macrophyte and rocks). Detailed substrate descriptions should be recorded in the field book, and the site locations must be marked on the lake map. If a map is unavailable, the lake should be sketched in the field book with the site locations clearly indicated with appropriate landmarks.

### Field Book Data Entry

For both sampling days (day 1 when the crayfish traps are set and day 2 when the traps are picked up) the following data should be clearly recorded in the field book:

#### Day 1 and Day 2

- lake name and date
- samplers' initials
- cloud cover (as a proportion of the sky, e.g., 0/10)

- water temperature
- air temperature, general weather and water conditions
- the time the traps are set/picked up at each site
- any atypical observations (e.g., whether the traps appeared to have been disturbed or moved)

#### Day 1

18 traps are set at each site. Traps are set in 3 lines perpendicular to the shore from 1 to 6 metres. Each line is set 5 metres apart from the next line. If the lake is too shallow to set to 6 metres, all the traps can be set out to a depth of 4 metres. This change must be recorded in the field book.

On day 1 the number of traps set per site must be recorded, as well as the total number of traps. This information is critical, since CPUE (catch per unit effort) cannot be determined if this number is unknown. If the lake is a survey lake, day 1 is the best day to record site/substrate descriptions, since more time will be needed on day 2 to record the crayfish catch data.

For each site there should be a description of the shoreline (i.e., 20% pine trees, 40% sedges, 40% rock (.5 to 1m in size), and of the substrate. Substrate texture classes are listed in Table 1 as described by LRTAP (Long Range Transport of Air Pollutants). Substrates should be described in approximate percentages as in the shoreline description (i.e., 20% logs, 50% cobble, 30% coarse sand). We have previously included the percentage of macrophytes present with the substrate description, but this should be entered as a separate percentage of macrophyte cover.

Any obvious landmarks for the site should also be recorded (i.e., 20 m to west of white boathouse).

#### Day 2

When collecting crayfish the first thing that should be recorded is the site number and the time. Crayfish information should always be recorded in the same sequence shown below:

| Line | Depth | Species | Sex | Carapace Hardness | Carapace Length | Remarks |
|------|-------|---------|-----|-------------------|-----------------|---------|
| 1    | 5     | OV      | FII | SH                | 33.6            | RCM     |

Please see Table 2 for description of codes used, and Table 3 for description of the remarks code as described by LRTAP.

This sequence of recording information facilitates ease of data entry when the results are entered into the ORACLE database from the field books.

Field books must be photocopied daily after returning from the field to ensure that the data is not lost, if the field book is lost or misplaced.

All crayfish are to be released with the exception of three crayfish (male FI, male FII and female) for each species from each survey lake to be kept for a reference collection. Any atypical or unidentified animals should also be saved for future reference/species verification. Crayfish that are brought back to the lab are to be placed in freezer bags correctly labelled (lake, date, species, sex) and placed in the freezer located in the biology storage trailer. Record details regarding the origin of these reference animals in the log book.

Table App.1

- see Table 1A for substrate classifications according to particle size.  
(Wentworth classification)

| Code | Description                                                                                                             |
|------|-------------------------------------------------------------------------------------------------------------------------|
| BDR  | Bedrock - continuous sheets of rock                                                                                     |
| BOU  | Boulder                                                                                                                 |
| COB  | Cobble                                                                                                                  |
| PEB  | Pebble                                                                                                                  |
| CSD  | Coarse Sand                                                                                                             |
| MSD  | Medium Sand                                                                                                             |
| FSD  | Fine Sand                                                                                                               |
| SLT  | Silt                                                                                                                    |
| CLA  | Clay                                                                                                                    |
| MUD  | Mud                                                                                                                     |
| FMN  | Ferromanganese nodules                                                                                                  |
| LOS  | Highly organic, flocculent, fine particle substrate composed largely of faecal pellets and commonly known as "Loonshit" |
| GRA  | Gravel                                                                                                                  |
| CPO  | Coarse particulate organic material (e.g., leaves, pine needles, small sticks)                                          |
| FPO  | Fine particulate organic material                                                                                       |
| LOG  | Submerged logs                                                                                                          |
| MAC  | Macrophytes; emergent e.g., cattails, sedges, water lilies<br>submergent e.g., myriophyllum                             |

Table App.1a

Substrate particle size terminology and categories.\*

| Modified classification<br>(Cummins 1961) | Wentworth classification |                           | Phi Scale  |
|-------------------------------------------|--------------------------|---------------------------|------------|
|                                           | Name                     | Particle size range in mm |            |
| Boulder                                   | Boulder                  | >256                      | -8         |
| Cobble                                    | Cobble                   | 64-256                    | -6, -7     |
| Pebble                                    | Pebble                   | 32-64                     | -5         |
|                                           |                          | 16-32                     | -4         |
|                                           |                          | 8-16                      | -3         |
|                                           |                          | 4-8                       | -2         |
| Gravel                                    | Granule                  | 2-4                       | -1         |
| Very coarse sand                          | Very coarse sand         | 1-2                       | 0          |
| Coarse sand                               | Coarse sand              | 0.5-1                     | 1          |
| Medium sand                               | Medium sand              | 0.25-0.5                  | 2          |
| Fine sand                                 | Fine sand                | 0.125-0.25                | 3          |
| Very fine sand                            | Very fine sand           | 0.0625-0.125              | 4          |
| Silt                                      | Silt                     | 0.0039-0.0625             | 5, 6, 7, 8 |
| Clay                                      | Clay                     | <0.0039                   | 9          |

\*After Cummins (1962).

Table App. 2

| Code                | Description of code entered in field book                                                                                                                                                                                                                           |                                 |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| Line -              | Trap lines at each site are numbered from left to right when facing the shore.                                                                                                                                                                                      |                                 |
| Depth -             | Depths simply refer to the depth of water the trap is set in. All floats are numbered from 1 to 6, and this number is recorded when the traps are retrieved on day 2 of sampling.                                                                                   |                                 |
| Species -           | Crayfish species are recorded by the first letter of the genus they belong to and the first letter of the species:                                                                                                                                                  |                                 |
|                     | Cambarus bartoni    Cb (1)                                                                                                                                                                                                                                          | Orconectes propinquus    Op (3) |
|                     | Cambarus robustus    Cr (2)                                                                                                                                                                                                                                         | Orconectes rusticus    Or (7)   |
|                     | Orconectes immunis    Oi (6)                                                                                                                                                                                                                                        | Orconectes virilis    Ov (4)    |
|                     | Orconectes obscurus    Oo (5)                                                                                                                                                                                                                                       |                                 |
|                     | Numbers in brackets refer to numerical coding used for species when the data is entered into the ORACLE database.                                                                                                                                                   |                                 |
| Sex -               | The symbol for female (♀) is used to record female crayfish. Male crayfish are recorded according to sexual maturity. Form I crayfish (sexually functional) are recorded as FI, and Form II crayfish (not sexually functional) are recorded as FII.                 |                                 |
|                     | Females are entered as 0, Form I males are entered as 1, and Form II males are entered as 2 in the ORACLE database.                                                                                                                                                 |                                 |
| Carapace Hardness - | Carapace hardness is a subjective rating of the hardness of the crayfish shell assigned by the sampler by gently squeezing the thorax of the crayfish between the thumb and the forefinger:                                                                         |                                 |
|                     | VS - very soft (a recent moult, the carapace tends to collapse with handling) (0)                                                                                                                                                                                   |                                 |
|                     | S - soft (1)                                                                                                                                                                                                                                                        |                                 |
|                     | SH - the shell is of medium hardness, but can be compressed easily (2)                                                                                                                                                                                              |                                 |
|                     | HS - the shell is of medium hardness, and can be compressed with considerable force (3)                                                                                                                                                                             |                                 |
|                     | H - hard (4)                                                                                                                                                                                                                                                        |                                 |
|                     | VH - very hard (5) usually stained with diatoms, very dark in colour                                                                                                                                                                                                |                                 |
|                     | Numbers in brackets refer to numerical coding used in data entry for the ORACLE database.                                                                                                                                                                           |                                 |
| Carapace Length -   | The dorsal carapace length is measured with vernier calipers. The length is the distance between the tip of the acumen (the extreme anterior end of the rostrum), and the posterior end of the cephalothorax; measured to one decimal place in mm. - e.g., 33.6 mm. |                                 |

Table App. 3 (Remarks, as defined by LRTAP)

| Condition | Crayfish Condition Indicators                                              |
|-----------|----------------------------------------------------------------------------|
| DED       | Dead specimen                                                              |
| RCR       | Right chela regenerated (DRC code only) i.e., right claw smaller than left |

|     |                                                                                                                                     |
|-----|-------------------------------------------------------------------------------------------------------------------------------------|
| LCR | Left chela regenerated (DRC code only) i.e., left claw smaller than right                                                           |
| RCM | Right chela missing                                                                                                                 |
| LCM | Left chela missing                                                                                                                  |
| CBM | Both chela missing                                                                                                                  |
| DAN | Damaged animal usually exoskeleton wounds                                                                                           |
| ACU | Acumen broken - affects carapace length measurement                                                                                 |
| NWI | Newly molted individual - very soft carapace                                                                                        |
| PMI | Pre-moult individual                                                                                                                |
| DSC | Dirty or stained carapace                                                                                                           |
| CGD | Cement glands developed                                                                                                             |
| PIT | Possibly infected with microsporidian parasite <u>Thelohania sp.</u> - abdominal muscle opaque                                      |
| DIT | Definitely infected with microsporidian parasite <u>Thelohania sp.</u> - abdominal muscle white                                     |
| BPA | Blue phase animal - blue colour                                                                                                     |
| FWE | Female with eggs (DRC code only): the colour and approximate number of eggs should be described with minimal handling of the animal |
| FWY | Female with young (DRC code only): the approximate number of young should be determined with minimal handling of the animal         |

\* NB - these codes are only intended as a guide; field notes should be made with sufficient detail so that the above information can be derived from the notes.

Please see Ron Reid, Kim Ralph or Ron Ingram should you need assistance with obtaining equipment, locating lakes or any other sampling problems.

If you have problems with crayfish identification please refer to the reference collection in the biology lab or see Keith Somers.



